Pa 426

THE LIBRARY
OF
THE UNIVERSITY
OF CALIFORNIA
DAVIS

Digitized by the Internet Archive
in 2012 with funding from
University of California, Davis Libraries

http://archive.org/details/californiajourna45cali

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

Volume 45 JANUARY 1949 Number 1

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

LIBRARY
UNIVERSITY OF CALIFORNIA
DAVIS

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T HANNUM, Director

DIVISION OF MINES
OLAF P. JENKINS, Chief

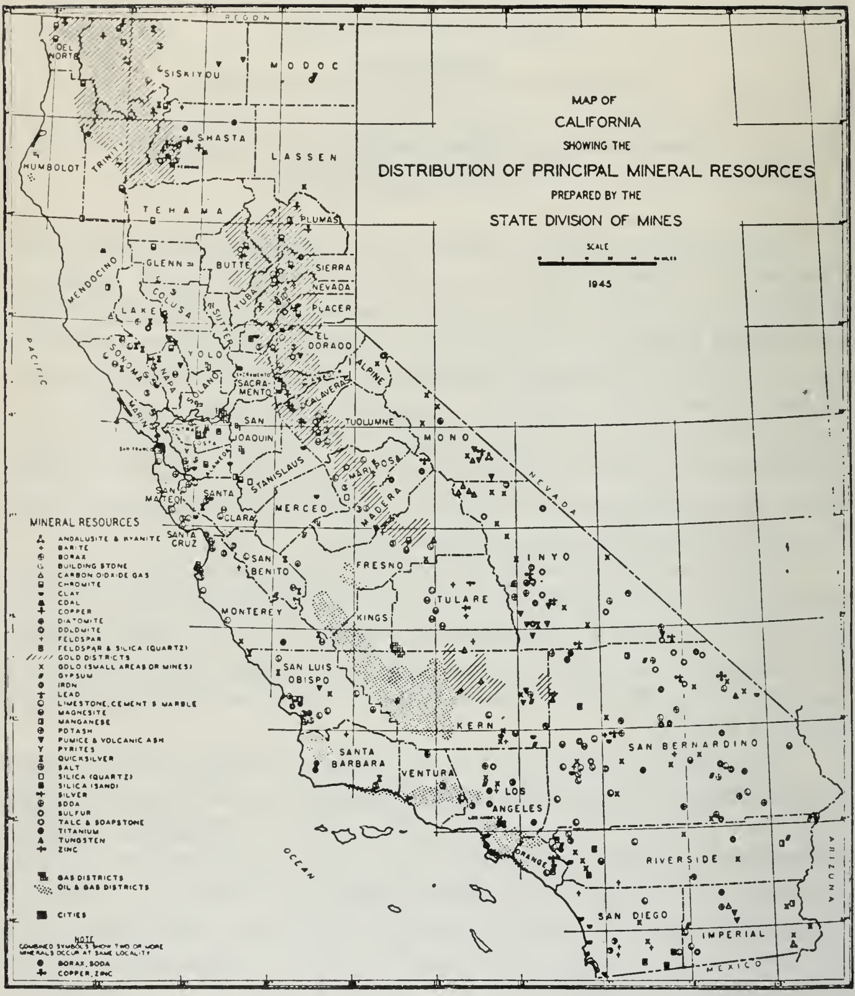
Headquarters
Third Floor, Ferry Building, San Francisco 11

District Offices
State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Box 445, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines are the quarterly **California Journal of Mines and Geology,** issued in January, April, July, and October of each year, and a series of **Bulletins. Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of publications will also be sent free upon request.


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES
SCALE
1945
MINERAL RESOURCES
ANDALUSITE & KYANITE
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY
BORAX, SODA
COPPER, ZINC
OREGON
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
PLACER
COLUSA
LAKE
SUTTER
YUBA
EL DORADO
SONOMA
NAPA
YOLO
SOLANO
SACRAMENTO
ALPINE
MARIN
AMADOR
CALAVERAS
TUOLUMNE
CONTRA COSTA
SAN JOAQUIN
ALAMEDA
MONO
SAN MATEO
STANISLAUS
MARIPOSA
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
SAN BENITO
FRESNO
INYO
MONTEREY
TULARE
KINGS
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
PACIFIC
OCEAN
NEVADA
ARIZONA
MEXICO

CONTENTS

Page

Annual Report, Division of Mines, for the Ninety-ninth Fiscal Year, July 1, 1947 to June 30, 1948, by Olaf P. Jenkins ---------------- 7

Quicksilver Deposits of the Oakville District, Napa County, California, by Philip F. Fix and C. Melvin Swinney ---------------- 31

Mines and Mineral Resources of Tuolumne County, California, by Clarence A. Logan ---------------- 47

Barium, by W. B. Winston ---------------- 85

Penn Mine Slag Dump and Mine Water, Calaveras County, California, by Frank J. Wiebelt and Spangler Ricker ---------------- 99

Division of Mines Publications Issued September 1, 1948 to November 30, 1948 ---------------- 107

Map Symbols Used in Publications of the U. S. Geological Survey --- 109

PLATES

Plate 1. Geologic map of La Joya mine, Napa County ---------------- In pocket

2. Underground workings of La Joya mine, Napa County ---------------- In pocket

3. Geologic map of the Bella Oak mine, Napa County ---------------- In pocket

4. Densmore mine, Tuolumne County ---------------- 56-57

5. *A*, Harvard mine, Tuolumne County. *B*, Eagle Shawmut mill, Tuolumne County ---------------- 56-57

6. *A*, Plant of Sonora Marble Aggregates Company, Tuolumne County. *B*, Old quarry of Columbia Marble Company, Tuolumne County ---------------- 56-57

7. *A*, View northwest from Columbia, across Tuolumne-Calaveras County marble belt. *B*, Limestone bedrock exposed by early-day placer mining at Columbia, Tuolumne County ---------------- 56-57

8. Map of Tuolumne County showing locations of mines ---------------- In pocket

ANNUAL REPORT, DIVISION OF MINES FOR THE NINETY-NINTH FISCAL YEAR, JULY 1, 1947 TO JUNE 30, 1948

(Part 2 of Biennial Report required by Section 2203, Public Resources Code)

By Olaf P. Jenkins *

OUTLINE OF REPORT

Page

Letter of transmittal 8

Introduction 8

Financial statement 9

Organization 9

Information service 10

Library section 12

Mineralogy section 15

Mineral economics 17

Mineral commodity survey 19

Basic geologic mapping 21

California cooperative investigations in geology 22

Publications 24

District offices 27

Ore-buyers' inspection 28

Plans for 100th fiscal year 29

---

* Chief, California State Division of Mines. Manuscript submitted for publication September 8, 1948.

LETTER OF TRANSMITTAL

General Warren T. Hannum
Director, Department of Natural Resources
Sacramento, California

SIR:

I have the honor to transmit herewith for reference to Governor Earl Warren the annual report of the Division of Mines for the 99th fiscal year, July 1, 1947, to June 30, 1948. This report constitutes Part 2 of the required biennial report.

Section 2203 of the Public Resources Code provides:

"The State Mineralogist shall make a biennial report to the Governor on or before the fifteenth day of September next preceding the regular session of the Legislature."

Since the state budget is now submitted annually to the Legislature for fiscal year appropriation of funds for the support of the state's administration, the Director of the Department has with the concurrence of the State Mining Board, directed that an annual fiscal report be submitted.

The public service and technical accomplishments of the Division during the 99th fiscal year have been highly praised, as attested by many letters and oral comments. The Division is requested to continue with this program of work and especially to cover areas on which no recent reports are available. A mineral market or mineral utilization survey in the regions about metropolitan areas has been requested by the Chambers of Commerce in San Francisco, Los Angeles, Bakersfield, and Redding. Work of this nature is within the functional scope of the Division but has not hitherto been done. The reason for its particular necessity at this time is that increased population and freight rates have brought new industries to the west coast and these industries are now looking for local sources of raw mineral materials. Most of the materials needed are nonmetallic minerals rather than metallic. The type of study required is basic geology, marketing, specifications, and methods of treatment.

Recently three new oil-producing districts have been developed in the state. The geological features of each of these were previously described in accurate accounts in the Division's Bulletin 118. As a result of this economic service by the Division the mineral fuels industry has strongly requested that the Division reprint Bulletin 118 and continue publishing supplementary chapters covering new fields and new and prospective areas. The basic geology as mapped and published on a quadrangle basis by the Division has found wide usage among mineral industries, especially the mineral fuels industry.

The following report covers the activities of the Division of Mines in the 99th fiscal year and represents the result of work planned and coordinated during the close of the 98th fiscal year.

Respectfully submitted,

Olaf P. Jenkins
Chief, Division of Mines (State Mineralogist)
September 15, 1948.

INTRODUCTION

The statutory functions of the Division of Mines were discussed in Part 1 of this biennial report [1] and conclusions were reached as to how the Division should be reorganized to comply with these functions and with the present needs of the mineral industry. This program of reorganization has proved successful as testified by the improved and extended service of the Division during the 99th fiscal year described in the following pages.

A special feature of Part 1 was a chapter on the mineral industry of California in 1947 prepared so as to describe briefly and in a general manner each mineral commodity of the state. At the time it was written however, the statistical record was known only in complete form for the year 1945. In the present report, production figures are given for both 1946 and 1947 showing the total mineral production by commodities. By the close of the calendar year 1948, final figures for the 1947 production of minerals by counties will be available to accompany a general report summarizing the mining activities in each of the state's 58 counties.

---

[1] Jenkins, Olaf P. Annual report, Division of Mines, for the ninety-eighth fiscal year, July 1, 1946 to June 30, 1947: California Jour. Mines and Geology, vol. 43, pp. 365-412, 1947.

FINANCIAL STATEMENT

Total salaries and wages		$136,303.46
Operating expenses:		
Office supplies	$2,453.98	
Office services	1,218.23	
Printing bulletins and maps	27,048.62	
Printing forms and stationery	872.95	
Telephone and telegraph	1,992.75	
Postage	1,997.43	
Freight, cartage, and express	649.45	
Travel	6,698.74	
Auto mileage	6.60	
Light, heat, and power	1,244.95	
Rent of premises	7,644.60	
Automobile—gas and oil, tires and tubes	2,703.49	
Automobile—services, and parts	2,200.00	
Blueprinting	94.20	
Photographic supplies	50.20	
Photographic services	30.20	
Laboratory	480.20	
Technical reports	8,200.00	
Repairs and maintenance	3,589.45	
Assays	3.00	
Exhibits	322.21	
Library	391.83	
Total operating expenses		69,893.08
Equipment:		
Automobile	$1,941.00	
Field	449.08	
Geology	2,502.45	
Laboratory	47.15	
Library	1,079.73	
Museum	71.37	
Office	1,950.55	
Photography	9.02	
Total equipment		8,050.35
Total expenditures		$214,246.89
Special item: Geological exploration in cooperation with U. S. Geological Survey		$50,000.00
Grand total		$264,246.89

ORGANIZATION

The basic plan for reorganization of the Division of Mines, as explained in Part 1 of this biennial report (annual report for 98th fiscal year) has been followed and crystallized during the 99th fiscal year, resulting in a distinct improvement in the administration and expansion in usefulness and activities of the Division. Two technical branches and one administrative branch form the basis of the organization. For the purpose of expediting the work, these branches are divided into sections.

The Geologic Branch consists of the following sections:

(a) Basic geologic mapping.
(b) Statewide mineral commodities survey.
(c) Mineralogy and petrography, including exhibits, research laboratories, and the determination of minerals and rocks.
(d) Geologic guidebooks (Highway 49 completed).
(e) Geological drafting.

The Mining Engineering Branch consists of the following sections:

(a) Information service (library work, oral and written communications and information service).
(b) Mineral economics survey (statistics, markets, and utilization of raw mineral materials).
(c) District offices which are engaged in making an inventory of active mining operations by counties; part of this work is done directly from the headquarters office in San Francisco.

The Administration Branch consists of the following sections:

(a) Publications, which includes technical editing and library research work in preparation of bibliographies and indexes.
(b) Office management, including fiscal control, preparation of budgets, office service, shipping, stocks, and maintenance.

All of these branches and sections are necessarily integrated with one another; in the integration of their work it is necessary at times to transfer some members of the staff from one section to another as the pressure of the work demands.

INFORMATION SERVICE

A marked improvement over previous years was made during the 99th fiscal year in the information service given to the public.

Reception Room. In the San Francisco headquarters office, a room has been set aside for interviewing the public, answering questions, and distributing publications. Information is supplied by personal interview, telephone conversation, correspondence, and the distribution of generalized mineral locality maps, descriptive mineral pamphlets, copies of mining laws, and *Mineral Information Service* (a monthly multigraph release), also the sale (at printing cost) of quarterly *Journals,* bulletins, and maps dealing with mining and geologic subjects.

Personal calls and interviews have increased from 900 to 1000 per month. The entire time of at least one engineer-geologist is devoted to answering questions and discussing mining, geologic, and related problems. Other engineers and geologists on the staff are constantly called upon to discuss certain phases of the mineral industry concerning which they have special knowledge. During the months of May and June, when the probability of an extension of the wartime moratorium on annual mining assessment work became apparent, more than 100 telephone calls were received daily on this subject alone, and 20 letters per day were received asking questions on the same topic. Ever-increasing numbers of persons, attracted by the California Centennial publicity, are seeking information on elementary gold placer mining and the placers where they may profitably retrace the steps of the forty-niners during a short vacation period.

Reading Room. A reading room containing current trade magazines and mining newspapers was opened in January. It serves about 10 persons per day.

Technical Library. A research technical library open to the public and used particularly by engineers and geologists serves about 70 persons per month, in addition to staff members of the Division who use it continually.

Museum. Throughout each day the public may be found examining with interest the various mineral displays and other exhibits in the museum; traffic amounts to about 50 persons per day.

Distribution of Publications. Subscribers to the *Journal* increased from about 275 in the 98th fiscal year to 630 in the 99th fiscal year. Much of the credit for this increase must be given to the free *Mineral Information Service* release, which, by its wide distribution, calls attention to Division of Mines publications.

During the 99th fiscal year, the Office Service section prepared some 4200 envelopes for mailing publications of the Division of Mines.

Mineral Information Service. In February 1948, the various types of mimeographed releases (Information Circulars, Announcements of New Publications, Commercial Mineral Notes) were finally consolidated into a monthly pamphlet under the title *Mineral Information Service.* This pamphlet is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. The following titles are representative of subject matter included in this monthly release: September Meeting of American Mining Congress, San Diego County Fair Gem and Mineral Exhibit, Chromite, Mica, Reference List of Recent Publications, Mining and Industrial News Notes, Domestic Uranium Production Program, New *Minerals of California,* Some Commodity Statistics for 1947, Selected References to Publications on Quicksilver in California.

Mineral Information Service was multigraphed in Sacramento by the Division of Administration, and was being sent to a mailing list of approximately 4500 addresses at the end of the 99th fiscal year, an increase during the year of about 1500 names. The Office Service Section makes about 275 new plates and change-of-address plates per month for the MIS mailing list.

Scores of letters from those who receive *Mineral Information Service* attest to the valuable service this pamphlet gives. Persons of all walks of life in the mineral industry—consultants, educators, mineralogists, engineers, geologists, laymen, etc.—seem to be more than pleased with this little pamphlet. On one or two occasions when its release has been delayed, there has been a regular stream of inquiries and protests. Many magazines, journals, and newspapers review or re-publish articles appearing in *Mineral Information Service,* crediting the Division of Mines as the source of the data.

Miscellaneous Mimeograph Releases. During the 99th fiscal year, the Office Service Section prepared approximately 12,000 mimeographed forms and releases.

Public Relations. During the 99th fiscal year, the Division of Mines furnished judges for the following County Fairs:

Amador County (August)
Mariposa County (August)
Lassen County (August)
Trinity County (August)
Shasta County (September)
El Dorado County (September)
Butte County (September)
Tulare-Kings Counties (September)
Kern County (September)
Third District Fair, Chico, Butte County (May)
Calaveras County (May)
San Diego County (June)

During the 99th fiscal year, the Division of Mines was represented at the following fairs:

(1) State Fair, Sacramento (September); displayed mineral exhibit.

(2) Assisted in arranging permanent exhibit at Exposition Park, Los Angeles.

(3) Exhibited $50,000 collection of gold nuggets and specimens at Jumping Frog Jubilee, Angels Camp; attended by 20,000 persons (May).

(4) Exhibited mineral specimens at Western Mining Council annual meeting at Friant, San Joaquin Valley (May).

LIBRARY SECTION

During the 99th fiscal year, the main research library was remodeled from the former reception room, a new reading room was constructed in the corner of the museum, and the old wooden bookcases were replaced by new steel shelving.

The average number of visitors to the main library per month was approximately 70 during the 99th fiscal year, and at least half of these were given personal assistance in finding references. The reading room served about 10 visitors per day. All current periodicals and new books of special interest to members of the technical staff were routed to them before the books were placed permanently on the shelves. These publications, together with the trade magazines and abstract journals, were examined and bibliographic references made and cataloged.

A survey was made of 245 libraries to determine the extent of their holdings of publications of the Division of Mines. The results of this survey were published in the October 1948 issue of the Journal. A considerable number of duplicate publications were exchanged with other libraries for publications needed by the Division of Mines. A list of the Division's library holdings of periodicals and newspapers was supplied to the local chapter of the Special Libraries Association for listing in the forthcoming ''Union List of Serials''.

Technical books were purchased for the district office libraries to the amount of $100.

The Geological Society of America established the library of the Division of Mines as a permanent depository for the Society's current publications which will now be received without charge. A supply of 50 copies each of 25 different duplicate publications covering mineral deposits of California was received by the library from the U. S. Geological Survey for free distribution. These were duly distributed to persons and institutions interested. Exchange of the Division's publications with other surveys, foreign governments, societies, and institutions was continued. In cooperation with the California Academy of Sciences, many sets of foreign publications were supplied to the Academy of Sciences in exchange for other courtesies. The binding of books for the library was continued to the extent of 61 volumes. Catalog cards, 150 in number, were secured from the Library of Congress for cataloging books of the Division of Mines.

In addition to the regular publications received from the federal government and state surveys, technical and scientific societies and institutions, both domestic and foreign, the following material has been received by the Division's library: periodicals on subscription from 26 technical and scientific concerns and 31 newspapers from mining centers; a large number of magazines representing house organs of corporations concerned with the mineral industries; folios, largely out of print, of the U. S. Geological Survey amounting to 80 in number donated by Robert Hawxhurst, Jr., mining engineer in San Francisco. The following titles represent publications acquired by the library of the Division of Mines during the 99th fiscal year.

Books Added to the Library During the 99th Fiscal Year
(D—Donation; E—Exchange)

1. American Association of Petroleum Geologists, Comprehensive index of A.A.P.G. publications, 1917-45, 1947.
2. (D) American Institute of Mining and Metallurgical Engineers Transactions, vol. 169, Milling and Concentration 1946 (Richards Memorial Volume), 1947.
3. Armstrong, E. Frankland, and Miall L. Mackenzie, Raw materials from the sea, Chemical Publishing Co., 1946.
4. Atwood, W. W., The physiographic provinces of North America, Ginn & Co., 1940.
5. Bennett, H., ed., Concise chemical and technical dictionary, Chemical Publishing Co., 1947.
6. Billings, Marland P., Structural geology, Prentice Hall Publishing Co., 1942.
7. Boggs, S. W., Classification and cataloging of maps and atlases, Special Libraries Association, 1945.
8. Bogue, R. H., Chemistry of portland cement, Reinhold Publishing Co., 1947.
9. (D) Buck, C. E., The business letter-writer's manual, Doubleday & Co., Inc., 1938.
10. Byerly, P., Seismology, Prentice Hall Publishing Co., 1942.
11. (E) California Blue Book, 1946.
12. Canadian Institute of Mining and Metallurgy Transactions, vol. 49, 1946, paper, Canadian Institute of Mining and Metallurgy, 1947.
13. (D) Chamber's mineralogical dictionary, first pub. 1945; new ed. 1948, Chemical Publishing Co., 1948.
14. Chapman, S., The earth's magnetism, London, Methuen, 1936.
15. Cotton, C. A., Volcanoes as landscape forms, Whitcombe & Tombs, Ltd., Christchurch, N. Z., 1944.
16. Dake, H. C., Fleener, F. L., and Wilson, B. H., Quartz family minerals, a handbook for the mineral collector, 7th pr., Whittlesey House, 1938.
17. Daly, R. A., The changing world of the Ice Age, Yale University Press, 1934.
18. Dana, E. S., A textbook of mineralogy, 4th ed., (revised and enlarged by W. E. Ford), John Wiley & Sons, Inc., 1932.
19. Deering's Public Resources Code of the State of California, including 1947 pocket supplement. Bancroft-Whitney Co., 1944.
20. De Ment, Jack, and Dake, H. C., Handbook of uranium minerals, Mineralogist Publishing Co., 1947.
21. De Mille, J. B., Strategic minerals, McGraw-Hill Book Co., Inc., 1947.
22. Drury, Aubrey, California: an intimate guide, Harper & Bros. Publishers, 1947.
23. Edwards, A. B., Textures of the ore minerals, Inst. Min. & Met., Melbourne, Australia, 1947.
24. Engineering index 1947, Engineering Index, Inc., 1948.
25. (D) Gerstaecker, F., California gold mines, Bio-books, Oakland, 1946.
26. Handbook of chemistry and physics, 30th ed., Chemical Rubber Publishing Co., 1947.

27. (D) Hanna, P. T. ed., The dictionary of California land names, ed. by Phil Townsend Hanna (ed. of Westways), Automobile Club of Southern California, 1946.
28. (D) Harrison, G. R., compiler, Massachusetts Institute of Technology wave length tables, John Wiley & Sons, Inc., 1946.
29. Harrison, Horace L. H., Examination, boring and valuation of alluvial and kindred ore deposits, Mining Publications, Ltd., London, 1946.
30. Harvey, C. E., A method of semi-quantitative spectrographic analysis, Applied Research Laboratory, Glendale, California, 1947.
31. Holmes, A., Petrographic methods (revised and reprinted), D. Van Nostrand Co., 1939.
32. Howard, J. H., Revised lapidary handbook, Greenville, S. C., 1946.
33. Ingerson, Earl, and Fleischer, Michael, The American Mineralogist Index to Volumes 21-30, 1936, Mineralogical Society of America, 1947.
34. Johannsen, A., A descriptive petrography of the igneous rocks, vols. 1-3, University of Chicago Press, 1932, 1937, 1939.
35. Johnson, D. W., Stream sculpture on the Atlantic slope, Columbia University Press, 1931.
36. Jones, Idwal, Vermilion, Prentice-Hall Publishing Co., 1947.
37. Jones, P. J., Petroleum production, vol. 2, Optimum rate of production, Reinhold Publishing Co., 1946.
38. Jones, P. J., Petroleum production, vol. 3, Oil production by water, Reinhold Publishing Co., 1947.
39. King, Clarence, Mountaineering in the Sierra Nevada, W. W. Norton & Co., Inc., 1936.
40. (D) Kirkbride, C. G., Chemical engineering fundamentals, McGraw-Hill Book Co., 1947.
41. (D) Kolthoff, Izaak M., and Lingane, J. J., Polarography, revised reprint, Interscience, 1946.
42. Kraus, E. H., and Slawson, C. B., Gems and gem materials, 5th ed., McGraw-Hill Book Co., 1947.
43. Lewis, R. S., Elements of mining, 2d ed., John Wiley & Sons, Inc., 1941.
44. Lindgren, W., Mineral deposits, McGraw-Hill Book Co., 1933.
45. Loomis, F. B., Field book of common rocks and minerals, G. B. Putnam's Inc., 1923.
46. Lyman, G. D., Ralston's ring, Chas. Scribner's Sons, 1937.
47. Macelwane, J. B., When the earth quakes, Bruce Publishing Co., 1947.
48. (D) Mackin, J. Hoover, Some structural features of the intrusives in the Iron Spring district (Guidebook to the geology of Utah, No. 2), Utah Geol. Soc., Salt Lake City, 1947.
49. (D) McKinstry, H. E., Mining geology, Prentice-Hall Publishing Co., 1948.
50. Meggers, Wm. F., and Scribner, Bourbon F., Index to the literature on spectro-chemical analysis, 1920-39, 2d ed., American Society for Testing Materials, 1941.
51. Mineral resources of the United States, by the staff of the Bureau of Mines and Geological Survey, Public Affairs Press, 1948.
52. National Research Council, Industrial research laboratories of the U. S., 8th ed., National Research Council, 1946.
53. Nelson, J. Raleigh, Writing the technical report, 2d ed., McGraw-Hill Book Co., 1947.
54. (D) Parsons, A. B., ed., Seventy-five years of progress in the mineral industry, 1871-1946, American Institute of Mining and Metallurgical Engineers, 1947.
55. Paul, Rodman, California gold, Harvard University Press, 1947.
56. Peattie, Roderick, ed., The Pacific Coast Ranges, Vanguard Press, 1945.
57. Peattie, Roderick, ed., The Sierra Nevada, The range of light, Vanguard Press, 1947.
58. Petroleum World, Annual review index, 1947.
59. Phillips, F. C., An introduction to crystallography, Longmans Green & Co., Inc., 1947.
60. Rice, C. M., Dictionary of geological terms (1947), Edward Bros., Ann Arbor, Mich., 1947.
61. Rickard, T. A., Technical writing, 3d ed., 1931.
62. Ries, H., and Watson, T. L., Elements of engineering geology, 2d ed., revised, John Wiley & Sons, 1947.

63. Sawyer, R. A., Experimental spectroscopy, Prentice-Hall, 1944.
64. Schuchert, Chas., Historical geology of the Antillean-Caribbean region, John Wiley & Sons, 1935.
65. Schwarzkopf, Paul, Powder metallurgy, its physics and production, The Macmillan Co., 1947.
66. Scribner, B. F., and Meggers, Wm. F., Index to the literature on spectrochemical analysis, Part II, 1940-1945, American Society for Testing Materials, 1947.
67. Shand, S. J., Eruptive rocks, their genesis, composition, classification and their relation to ore deposits, 3d ed., John Wiley & Sons, 1948.
68. Shillaber, Photo micrography, John Wiley & Sons, 1944.
69. Smith, Orsino C., Identification and qualitative chemical analysis of minerals, D. Van Nostrand Co., 1946.
70. Spencer, L. J., A key to precious stones, Emerson Books, 1946.
71. (D) Sverdrup, H. U., et al., The oceans, their physics, chemistry and general biology, Prentice-Hall, 1946.
72. Thomas' Register of American Manufacturers, 38th ed., (3 vols. and index), Thomas Publishing Co., 1948.
73. Trelease, Sam F., The scientific paper, how to prepare it, how to write it, Williams & Williams, 1947.
74. (E) Tyler, Paul M., From the ground up, McGraw-Hill, 1948.
75. (D) U. S. Bureau of Land Management, Manual of instructions for the survey of the public lands of the United States, Washington, 1947.
76. (E) U. S. Bureau of Mines, Minerals Yearbook, 1945.
77. (D) U. S. Bureau of the Census, County Data Book, 1947.
78. (E) U. S. Bureau of the Census, Statistical abstract of the United States, 1947
79. U. S. Office of military government for Germany, The manufacture of refractories, PB 37804, Mapleton House, 1946.
80. Wahlstrom, E. E., Igneous minerals and rocks, John Wiley & Sons, 1947.
81. Weeks, B. M., How to file and index, Ronald Press, 1946.
82. Weston, Otheto, Mother Lode album, Stanford University Press, 1948.
83. Winchell, A. N., Elements of mineralogy, Prentice-Hall 1942.
84. Winchell, A. N., Microscopic characteristics of artificial minerals, inorganic substances, 2d ed., John Wiley & Sons, 1931.
85. Worcester, P. G., A textbook of geomorphology, D. Van Nostrand Co., 1939.
86. Zielke, C. B., How to take industrial photographs, McGraw-Hill, 1948.
87. Zim, Herbert S., and Cooper, Elizabeth K., Minerals, Harcourt Brace & Co., 1943.
88. Zimmerman, O. T., and Lavine, Irvin, Conversion factors and tables, Industrial Research Service, Dover, N. H., 1944.
89. Zimmerman, O. T., and Lavine, Irvin, Scientific and technical abbreviations, signs, and symbols, Industrial Research Service, Dover, N. H., 1948.

MINERALOGY SECTION

Laboratory. A total of 1926 samples was received and determined in the Division of Mines laboratory during the 99th fiscal year. A decided increase for the last six months over the first six months of the 99th fiscal year indicates an increased interest on the part of the public in the services rendered by the mineral testing laboratory of the Division of Mines. The service and accuracy of the work were greatly improved by thorough and careful testing and checking in the laboratory. By far the largest number of samples submitted for determination consisted of quartz and other minerals of the quartz group. Although a great deal of interest still persists in gold, silver, copper, lead, and zinc, a large proportion of the samples received were nonmetallic. There is also an increased interest in radioactive metals and a large number of requests were submitted for tests of radioactivity and uranium. More samples probably will be submitted during the next fiscal year than were submitted during any of the previous fiscal years.

Museum. Many new specimens were received by the Museum; some were outstanding. Among these specimens recently catalogued for the museum are the following:

21294 VARICITE ($AlPO_4.2H_2O$), a hydrous aluminum phosphate, from north of Lucin, Utah. Donor: R. F. Henley, August 11, 1948.

21295 MANGANESE ORE (high grade), from 2 miles north of Tatu Station, Mendocino County, California. Donor: Eugene A. Bacchi, August 11, 1947.

21296 PLUME AGATE, from near San Luis Obispo, San Luis Obispo County, California. Donor: Gordon Bowser, August 1947.

21297 CASSITERITE (SnO_2) (high grade) and dredge concentrates from property of Portuguese-American Tin Company in Castelo Branco district, Portugal. Donor: R. E. Gruber, August 1947.

21298. BARITE ($BaSO_4$) (roses), from Caliente Range, about 10 miles south of Taylor Springs in San Luis Obispo County, near the Santa Maria-Mariposa highway. Donor: George F. Kray, August 1947.

21299 STILBITE, from Coffon Butte, Benton County, Oregon. Donor: Robert Prather, August 1947.

21300 BARITE CRYSTALS ($BaSO_4$) with limonite varnish, from Big Creek antimony mine, Austin, Nevada. Donor: Tony Romano, October 1947.

21301 OPALIZED WOOD, from Churchill County, Nevada, on State Highway 23, about 13 miles south of U. S. Highway 50. Donor: R. F. Henley, November 10, 1947.

21302 PETRIFIED PALM ROOT, from Calico Mountains, San Bernardino County, California. Donor: R. F. Henley, November 10, 1947.

21303 PETRIFIED TREE LIMB, from near Redmond, Oregon. Donor: R. F. Henley, November 10, 1947.

21304 KERNITE ($Na_2B_4O_7.4H_2O$), a hydrous sodium borate, from mines of the Pacific Coast Borax Company at Kramer, Kern County, California. Donor: Pacific Coast Borax Company, October 22, 1947.

21305 JADE (nephrite), from tide-lands 15 miles south of Big Sur, Monterey County, California. Donor: F. A. Luis, October 1947.

21306 PYRITE in slate, from Argonaut mine, Greenwood, El Dorado County, California. Donor: Oliver C. Dupuis, October 1947.

21307 ARAGONITE ($CaCO_3$), from ocean cliffs north of mouth of Willow Creek, Monterey County, 8 miles northwest of county's southern border. Donor: R. F. Henley, November 6, 1947.

21308 CARNOTITE (approx. $K_2O.2UO_3.V_2O_5.2H_2O$). An important ore of uranium and vanadium, from Crown Prince mine in Vixen mining district, Paradox Valley, Colorado. Donor: C. Richard Redington, November 1947.

21309 BERYLLIUM POWDER. Donor: Marty Hess, November 1947.

21310 MAGNESITE ($MgCO_3$) with CHALCEDONY (SiO_2), from near head of Orestimba Creek, west of Newman, Stanislaus County, California. Donor: A. M. Husong, November 1947.

21311 LIMONITE (iron ore), from Mesabe Range, Hibbing district, Hibbing, Minnesota. Donor: A. R. Anderson, January 1948.

21312 LIMONITE (iron ore), polished pieces from Mesabe Range, Hibbing district, Hibbing, Minnesota. Donor: A. R. Anderson, January 1948.

21313 QUARTZ PSEUDOMORPH AFTER NATROLITE, from 3 miles north of Calico, San Bernardino County, California. Donor: Wilfred C. Eyles, February 24, 1948.

21314 PETRIFIED PALM, from proposed site of Iron Canyon dam, near Red Bluff, Tehama County, California. Donor: C. E. Wheeler, March 5, 1948.

21315 PETRIFIED YUCCA, from the proposed site of Iron Canyon dam, near Red Bluff, Tehama County, California. Donor: C. E. Wheeler, March 5, 1948.

21316 CALAMINE (stalactitic), from Bleischarley, Poland. Donor: George C. Heikes, February 1948.

21317 LAWSONITE ($H_4CaAl_2Si_2O_{10}$), pinkish-colored crystals on massive fibrous GLAUCOPHANE ($Na(Al,Fe)(SiO_3)_2$), from $2\frac{1}{2}$ miles northeast of Valley Ford, Sonoma County, California. Donor: Charles W. Chesterman, March 22, 1948.

21318 GLAUCOPHANE ($Na(Al,Fe)(SiO_3)_2$), radiating blue crystals in CLINOZOISITE ($HCa_2Al_3Si_3O_{13}$), from $2\frac{1}{2}$ miles northeast of Valley Ford, Sonoma County, California. Donor: Charles W. Chesterman, March 22, 1948.

21319 COLEMANITE ($Ca_2B_6O_{11}.5H_2O$) crystals from cavities in the Little Biddy-McCarthy mine, near Ryan, Inyo County, California. Donor: Donald L. Seal, March 24, 1948.

21320 AXINITE ($H(Ca,Mn,Fe)_3BaAl_2(SiO_4)_4$), in well-developed crystals with EPIDOTE ($HCa_2Al_3Fe_3Si_3O_{13}$) and CALCITE ($CaCO_3$), from south end of Butte Valley, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21321 AURICHALCITE, a basic carbonate of zinc and copper, $2(Zn,Cu)CO_3.3(Zn,Cu)(OH)_2$, from 1 mile east of Dodd Spring, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21322 CHRYSOTILE ($H_4Mg_3Si_2O_9$), from 2 miles east of Racetrack, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21323 GARNET, probably andradite ($Ca_3Fe_2(SiO_4)_3$). Garnet crystals showing the dodecahedron modified by the trapezohedron. In a matrix of garnet and chrysocolla. From 1 mile southeast of Lost Burro Spring, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21324 CALCITE ($CaCO_3$). Red, banded calcite from 1 mile east of Racetrack, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21325 SERPENTINE ($H_4Mg_3Si_2O_9$), cut by veinlets of chrysotile, from Talc claim, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21326 SCAPOLITE (intermediate between $CaCO_3.3CaAl_2Si_2O_8$ and $NaCl.3NaAlSi_3O_8$), with chrysocolla, from 3 miles east of Dodd Spring, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21327 ADULARIA ($KAlSi_3O_8$), variety of orthoclase feldspar. Crystals in matrix. From 3 miles east of Dodd Spring, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21328 CALCITE ($CaCO_3$), pink cleavage fragment from Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21329 PLEONASTE, iron-magnesia spinel, $(Mg,Fe)O.Al_2O_3$, from south end of Butte Valley, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21330 LIMONITE ($HFeO_2.nH_2O$) pseudomorphous after pyritohedral pyrite, from Talc mine, 3 miles east of Racetrack, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21331 MAGNESITE ($MgCO_3$), from 2 miles northwest of Gold Belt Spring, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21332 GEHLENITE ($Ca_3Al_2Si_2O_{10}$), in matrix, from 2 miles east of Lost Burro Spring, Ubehebe mining district, Inyo County, California. Donor: Death Valley Curley, April 1948.

21333 EMERALD ($Be_3Al_2(SiO_3)_5$) artificial. Manufactured by Chatham Research Laboratories, San Francisco, California. Donor: Earl P. Chatham, March 1948.

21334 SILVER, leaf and wire, from sulphide zone below the 2000-foot level, Chief mine No. 2, Tintic mining district, Juab County, Utah. Donor: Howard Fitch, April 1948.

21335 COLEMANITE ($Ca_2B_6O_{11}.5H_2O$), tabular crystals, from Lila C mine, 5 miles southwest of Death Valley Junction, Inyo County, California. Donor: Charles W. Chesterman, April 1948.

21336 COLEMANITE ($Ca_2B_6O_{11}.5H_2O$), tabular crystals in cavity, from Lila C mine, 5 miles southwest of Death Valley Junction, Inyo County, California. Donor: Charles W. Chesterman, April 1948.

21337 MERUMITE (Cr_2O_3) from Irang River placers in the Merume River Basin, British Guiana. Donor: Paul Donlay, May 18, 1948.

MINERAL ECONOMICS

Final mineral production figures, together with other pertinent discussions of mineral economics for 1945 were issued by the Division of

Mines in July 1947 as Bulletin 137; for 1946, in April 1948, as Bulletin 139. Distinct improvement was made in this latest annual report for 1946 by the inclusion of a discussion of each mineral commodity produced in the state. In the statistical bulletin for 1947 it is intended that descriptions will be included on the principal mining activities in each of the 58 counties of the state.

Advance press releases are issued by the Division as the statistical data are secured. Preliminary estimates for 1947 total mineral production were published in the January-February issue of Mineral Information Service. Final figures for some of the commodities were released in the succeeding issues of this pamphlet.

By means of agreement with the U. S. Bureau of Mines, approved and signed by State Directors of Finance and Natural Resources, Federal Director of the Bureau of Mines, and Chief of the State Division of Mines, a cooperative agreement has been reached as regards the collection of statistical data.

"This agreement made and entered into this 1st day of May, 1948, between the United States Bureau of Mines and the Division of Mines of the State of California for cooperation in the collection of statistical data:

"In order to avoid duplication of requests for statistical information of mine and quarry operations, and also in order that the State Division of Mines may be kept in touch with the mineral producers of the State, the following agreement between the Chief, State Division of Mines, and the Director of the United States Bureau of Mines is made for the collection of statistics of mineral production (with the exception of oil and gas) for 1947 and subsequent years. The type and scope of statistics to be secured from producers will be determined by consultation between the Bureau and the Division in order to comply with Section 2205 (b) of the California Public Resources Code.

"As soon as possible after the first of December, in each year, a numbered list of the mineral producers in the State (a duplicate of the working list of the Federal Bureau of Mines) will be sent by the Bureau of Mines to the Chief, Division of Mines to be retained for his files. The Chief will check the data with the records of his office and will notify the Federal Bureau of Mines at once of any additions and corrections to the list he deems advisable. These corrections will be made on the list of the Federal Bureau of Mines, properly numbered, and the Division of Mines will be advised of the list number given.

"The blanks for the collection of the statistical data from mineral producers will be printed at the expense of the United States Bureau of Mines and stamped 'In cooperation with the Division of Mines, Department of Natural Resources, State of California, under Division 2 of the California Public Resources Code.' The Statistical inquiries will be mailed from the United States Bureau of Mines.

"The second statistical inquiry will be prepared in the Federal Bureau of Mines in the same manner as the first inquiry. The third will be sent by registered mail. This procedure will be so scheduled as to provide annually for receipt by the Bureau of Mines, by March thirty-first, of all statistical reports from mineral producers. If this procedure does not produce satisfactory results, the Chief, Division of Mines, will endeavor to induce delinquent respondents to cooperate in the Federal Bureau's voluntary statistical collection program, by personal visits of himself or his assistants or by such other means as he may deem advisable.

"The returns from the operators will not be forwarded through the Division of Mines but will be received by the Federal Bureau of Mines direct from the operators, provided, however, that the Chief, Division of Mines, may invoke his powers under Sections 2207 and 2208 of the California Public Resources Code, and may supply information so obtained to the Federal Bureau of Mines.

"The figures covering the total output of each mineral in the State, with such county break-down as is possible without revealing information obtained in confidence, will be sent to the Division of Mines as soon as the compilation of the data is completed. Figures representing the output of LESS THAN THREE PRODUCERS shall not be disclosed, unless the Federal Bureau of Mines has obtained in writing authorization therefor from the producers interested.

> "In publications relating to the minerals covered by this cooperative agreement, issued by either the Federal Bureau of Mines or the Division of Mines, proper credit for cooperation shall be given.
>
> "The term of this agreement shall be from May 1, 1948 to April 30, 1953, inclusive, but shall be subject to termination by either party at any time during the term upon giving sixty days' written notice to the other party."

The accompanying table showing California mineral production for 1946 and 1947 is one of the results of this agreement. Other detailed statistical data are being published in Mineral Information Service as they are transmitted from the Federal Bureau of Mines to the State Division of Mines.

Preliminary estimated figures for the production of minerals in California for the first half of 1948 indicate that petroleum and natural gas output will exceed that of 1947 slightly in quantity and considerably in value, since four increases in the price of petroleum were made during 1947 amounting to approximately $1 per barrel on all grades.

There is some indication that coal again will be mined in California. Operators of a plant at Ione, which is now completed, will extract montan wax and mineral pigment from lignite and will shape the residue into briquets and sell them as fuel. Two companies have done preliminary work in 1947-48 in developing coal in Mendocino County.

Information now available for the first half of 1948 indicates a slight increase in the production of gold, silver, and lead, but a decreased output of copper-zinc and quicksilver. Only two important quicksilver mines are producing. All the copper-zinc mines in the state have been shut down, except one in Shasta County which is being equipped for production. Small zinc output is coming from lead mines. The monthly reports from cement mills in 1948 show a slight increase over 1947.

A study of the marketing of minerals in California has been started by the Division of Mines. The first results of this program have been published, namely, on pumice and perlite as industrial minerals, on soda ash and saltcake, and on the quicksilver industry which has been greatly disturbed because of imports from Spain and Italy. A market directory has been prepared to bring producers of minerals in contact with consumers.

MINERAL COMMODITY SURVEY

A detailed field geological study of mineral commodities, especially of nonmetallics, is being carried on by the Division of Mines. Results of extensive statewide studies on the detailed geology of quicksilver, chromite, manganese, and iron have already been published. A large bulletin on copper is in press. A manganese supplement is in preparation. The reports on most of these strategic minerals have been contributed by the federal Geological Survey, though published by the State Division of Mines.

A statewide report on limestone was issued by the Division during the 99th fiscal year. A field study of nonmetallics resulted in a series of published papers on foundry sands. Field work is under way on talc, pumice, perlite, and gypsum, and this work has attracted much interest and cooperation from industry.

In the study of sand, 28 occurrences were visited and a paper on the properties of foundry sands was contributed for publication by a famous authority. The field work on talc consisted of detailed plane-table mapping in three principal producing areas in San Bernardino County and

Mineral production of California in 1946-47 *

(Certain 1947 figures are preliminary)

Product	1946		1947	
	Quantity	Value	Quantity	Value
Aluminum ---- short tons	------	------	------	------
Andalusite ---- short tons	------	------	------	------
Antimony concentrates ---- short tons	------	------	------	------
Arsenious oxide ---- short tons	(1)	(1)	(1)	(1)
Asbestos ---- short tons	(2)	(2)	(2)	(2)
Asphalt (native) ---- short tons	(2)	(2)	(2)	(2)
Barite ---- short tons	(2)	(2)	(2)	(2)
Boron minerals ---- short tons	430,689	$9,575,866	501,935	$11,844,108
Bromine ---- pounds	(2)	(2)	(2)	(2)
Calcite (Iceland spar) ---- pounds	(3)	(3)	(3)	(3)
Calcium chloride ---- short tons	9,979	170,994	7,968	111,950
Cement ---- barrels	20,173,231	33,906,675	22,846,458	46,536,749
Chromite ---- short tons	(2)	(2)	948	(2)
Clay:				
Products, heavy clay (other than pottery and refractories)	------	[4]12,175,000	------	[4]14,600,000
Raw ---- short tons	[5]1,670,305	[5]2,254,164	[5]1,950,076	[5]2,965,360
Coke ---- short tons	260,470	(2 6)	332,244	(2 6)
Copper ---- pounds	8,480,000	1,373,760	4,814,000	1,010,940
Diatomite ---- short tons	(2)	(2)	(2)	(2)
Feldspar (crude) ---- long tons	------	------	(2)	(2)
Ferro-alloys ---- short tons	7,414	(2 6)	(2 6)	(2 6)
Fluorspar ---- short tons	------	------	------	------
Fullers earth ---- short tons	(2)	(2)	(2)	(2)
Gem stones	------	(3)	------	(3)
Gold ---- troy ounces	356,824	12,488,840	431,415	15,099,525
Gypsum (crude) ---- short tons	574,345	1,315,699	811,798	1,996,157
Iodine ---- pounds	(2)	(2)	(2)	(2)
Iron:				
Ore ---- long tons	226,062	(2)	373,574	(2)
Pig ---- short tons	344,024	(2 6)	453,376	(2 6)
Kyanite ---- short tons	(2)	(2)	(2)	(2)
Lead ---- short tons	9,923	2,163,214	10,080	2,903,040
Lime ---- short tons	172,623	2,144,712	181,296	2,615,599
Lithium minerals ---- short tons	(2)	(2)	(2)	(2)
Magnesite ---- short tons	(2)	(2)	(2)	(2)
Magnesium ---- short tons	56	21,664	------	------
Magnesium compounds (natural) ---- pounds	111,906,000	2,814,979	133,206,000	2,898,880
Manganese ore ---- short tons	------	------	------	------
Manganiferous ore ---- short tons	------	------	------	------
Mercury ---- flasks (76 pounds)	17,782	1,746,904	17,165	1,437,397
Mica, scrap ---- short tons	(2)	(2)	(2)	(2)
Mineral waters	(3)	(3)	(3)	(3)
Molybdenum ---- pounds	(2)	(2)	(2)	(2)
Natural gas ---- M cubic feet	487,904,000	143,790,000	540,000,000	159,800,000
Natural gasoline and allied products:				
Nat. gasoline and cycle prods. ---- gallons	734,227,000	32,085,000	837,313,000	45,812,000
Liquefied petroleum gases ---- gallons	176,311,000	4,933,000	233,546,000	8,174,000
Ores (crude), etc.:				
Copper ---- short tons	86,297	(7)	15,993	(7)
Dry and siliceous (Au and Ag) ---- short tons	335,657	(7)	449,792	(7)
Lead ---- short tons	57,330	(7)	87,913	(7)
Zinc ---- short tons	45,043	(7)	49,651	(7)
Zinc-copper ---- short tons	99,176	(7)	35,745	(7)
Zinc-lead ---- short tons	4,264	(7)	9,695	(7)
Peat ---- short tons	8,137	105,242	(2)	(2)
Pebbles for grinding ---- short tons	74	927	30	362
Perlite ---- short tons	886	4,873	------	------
Petroleum ---- barrels	314,713,000	387,100,000	333,102,000	571,688,000
Platinum metals (crude) ---- troy ounces	67	(2)	324	(2)
Potassium salts ---- short tons	(2)	(2)	(2)	(2)
Pumice ---- short tons	89,181	755,570	140,000	940,000
Pyrites ---- long tons	(2)	(2)	(2)	(2)
Quartz crystal ---- pounds	------	------	(3)	(3)
Salt (sodium chloride) ---- short tons	729,092	3,358,060	768,397	3,810,898
Sand and gravel ---- short tons	27,220,849	18,396,460	31,387,000	25,339,000
Sand and sandstone (ground) ---- short tons	(2)	(2)	(2)	(2)
Silica (quartz) ---- short tons	(2)	(2)	(2)	(2)
Silver ---- troy ounces	1,342,651	1,084,862	1,597,442	1,445,685
Slate	------	(2)	------	(2)
Sodium salts (carbonates and sulfates) (natural) ---- short tons	(2)	(2)	(2)	(2)
Stone ---- short tons	[8]8,950,320	[8]8,452,083	[8]12,757,790	[8]13,012,556
Strontium minerals ---- short tons	243	3,726	------	------
Sulfuric acid (60° B.)[9] ---- short tons	(2 6)	(2 6)	(2 6)	(2 6)

*Mineral production of California in 1946-47 *—Continued*

(Certain 1947 figures are preliminary)

Product	1946		1947	
	Quantity	Value	Quantity	Value
Sulfur ore .... long tons	757	11,835	698	9,074
Talc, pyrophyllite and gr. soapstone ...... short tons	78,170	1,434,978	91,537	1,595,422
Tin (metallic equivalent) .... short tons	------	------	------	------
Tungsten concentrates (60% WO_3 basis) short tons	1,262	1,117,855	394	548,233
Zinc .... short tons	6,877	1,677,988	5,415	1,245,450
Miscellaneous[10]	------	25,336,529	------	35,281,630
Total value, eliminating duplications	------	$700,086,000	------	$958,219,000

[1] Figure not available.
[2] Value included with "Miscellaneous."
[3] No canvass.
[4] Figures obtained through cooperation with Bureau of the Census.
[5] Sold or used; value of clay used in cement and heavy clay products not included in total value for state.
[6] Value not included in total value for state.
[7] Not valued as ore; value of recoverable metal content included with the metals.
[8] Exclusive of marble, value for which is included with "Miscellaneous."
[9] From lead smelting.
[10] Includes minerals indicated by "(2)" and "(8)" above.
* Prepared by Bureau of Mines, U. S. Department of the Interior.

many others in Inyo County. The California Institute of Technology cooperated in the preparation of thin sections of rocks for microscopic study and members of the talc industry cooperated in the field investigation.

Field geologic study of perlite and pumice is being carried on to supplement an economic study which has been completed. Deposits have been mapped in the following counties: Inyo, Kern, Lassen, Modoc, Mono, Napa, San Bernardino, Siskiyou, Sonoma.

The gypsum investigation has just been started but will include an extensive study throughout southern California.

BASIC GEOLOGIC MAPPING

In order to intelligently and adequately explore and develop the mineral commodities of the state, it is necessary to map the basic geology. A carefully conducted statewide program of basic mapping of the rock formations and geological structure by quadrangle units is well under way by the Division of Mines. For the most part, this basic work is being done through cooperative programs: (a) cooperation with research geological departments of the universities through contributions in part purchased at a nominal rate by means of budgetary support, item "purchase of reports and maps" amounting to approximately $10,000 per year; (b) cooperation with the federal Geological Survey on a fifty-fifty basis, the state contributing $50,000 per year.

The university work for the most part represents mapping geology on 15-minute (scale 1:62,500) quadrangles, the topography of which has been published by the U. S. Geological Survey. New topographic maps are now available through the cooperative mapping program carried on between the state (Division of Water Resources) and the U. S. Geological Survey. The location of mineral deposits and discussion of them is done by members of the Division's staff and this economic work is coordinated with the more purely scientific research carried on by the universities.

The following geologic quadrangle maps are in preparation or actually in press.

In press

Copperopolis
Hollister
Lake Elsinore
Santa Rosa
Sonoma
Carquinez
Mt. Vaca
Vacaville
Pt. Reyes
Petaluma
Mare Island
Antioch

Nearly ready for press

Blue Lake
Cuyamaca Peak
Gasquet
Neenach
Quien Sabe
Santa Barbara County (3 quadrangles)
Nipomo

Nearly completed

Ivanpah
Ubehebe
Macdoel
Priest Valley
St. Helena
San Fernando (4 quadrangles)
San Jose

In preparation

Mother Lode (2 quadrangles)
Barstow
Bishop (4 quadrangles)
Cerro Gordo (4 quadrangles)
Lebec
Markleeville
Mt. Hamilton
Weaverville (4 quadrangles)
Blairsden
Bridgeport
Capay
Fort Ross (4 quadrangles)
Healdsburg
Imperial Valley (13 quadrangles)
Monterey County (15 quadrangles)
Morgan Hill
Rumsey
Santa Paula
Sebastopol
Ventura

The federal geologic mapping is being done on a larger base, for the most part on 7½-minute quadrangles (scale 1:24,000, or 1 inch to 2,000 feet). The areas chosen for mapping are distinctly mineral belts and special attention is given to the occurrences and formation of mineral deposits. A report on cooperative program follows.

CALIFORNIA COOPERATIVE INVESTIGATIONS IN GEOLOGY

(Annual Report—99th Fiscal Year, 1947-48
Submitted by United States Geoloical Survey)

"In fiscal 1948, the third year of geological surveys in California under the cooperative program of the United States Geological Survey and the State Division of Mines, work was sustained at a rate that brought the expenditures for the year above the $100,000 that the two agencies, under their agreement, were to provide in equal shares. Direct expenditures for the year were $105,000.00, of which the State will pay $50,000 and the Survey the remainder. The principal activities throughout the year continued to be the field mapping and laboratory investigation of the geology of five mining areas—all major investigations started during preceding years. These major projects are studies of the Shasta copper belt, the Mother Lode gold belt, the Bishop tungsten area, the Cerro Gordo-Ubehebe lead-zinc area, and the San Diego pegmatite belt.

"The general state of the work on the major projects, except on that in San Diego County, is about the same for all: Detailed examinations of substantial parts of each area have established the nature of the mappable rock units and their general distribution in the entire areas, but mile-by-mile coverage to work out the geologic structure remains to be done. The relation of the ore deposits to the rock units and geologic structure has been partly worked out, through detailed examination of the principal deposits as they may be accessible in the areas mapped. It is estimated that two or more years additional field work (the rate depending on availability of personnel) will be required for Shasta copper, Mother Lode, and Bishop field work, about a year for Cerro Gordo-Ubehebe. The San Diego pegmatite field work was nearly complete at the end of the year, and a final report is scheduled for completion six months later.

"Minor projects include the investigation of the geology of two California limestone deposits and the geologic mapping of the West Point-Electra water tunnel east of the Mother Lode. The cooperative program provided funds for geologic investigations at the New Almaden quicksilver project only through the first quarter of the year, during completion of field work; Geological Survey funds are carrying this major project during the additional year required for completion of a report on the geology.

"The program engaged the full time of 11 geologists and one clerk, plus the part-time or intermittent work of nine other geologists and one clerk. The figures for cost and personnel do not include administrative, technical, and scientific services of the Washington staff of the Survey, nor do they include the work of Survey geologists who prepared reports based on war-time investigations of California mineral resources such as quicksilver, chromite, manganese, and iron for publication by the State Division of Mines. The cost to the Federal Survey of preparing these reports exceeded $5,000.

"Active Projects, Fiscal 1948

Shasta Copper Belt. During the year the main geologic map, scale 1:24,000, was extended northward and northeastward from the eastern half of the Weaverville SE. 15-minute quadrangle previously mapped. Mapping is now completed for approximately half of the six 7½-minute quadrangles that are needed for a minimum coverage of the copper belt. About two-thirds of the year was devoted to a detailed study of the geology at the Iron Mountain mining area. The mining company generously cooperated and made available detailed maps of the topography and mine workings, as well as much information about the results of mining and diamond drilling. A geologic report on the Iron Mountain deposit was 80 percent complete at the end of the fiscal year.

"*Mother Lode Gold Belt.* Investigations in the Mother Lode continued to be concentrated on the general geology, which is being mapped on a scale of 1:24,000. During the year the geologic map of the San Andreas No. 4 7½-minute quadrangle was completed, and at the end of the year a report on it was 90 percent complete. The geology of the Sonora 7½-minute quadrangle was 90 percent complete. At the rate of work in fiscal 1948, it would require 4 years more to complete the eight 7½-minute quadrangles desired for adequate coverage of the northern part of the Mother Lode. The demands for work on other metals more urgently required by the national needs make it doubtful that the mapping can be continued at that rate.

"*West Point-Electra Water Tunnel.* The geology exposed during the driving of an 11-mile water tunnel near West Point and Electra, east of the Mother Lode, was mapped by geologists of the Mother Lode party. Access to the tunnel was through the courtesy of the Pacific Gas and Electric Company. By the end of the year, about 5 man-months had been spent on this geologic mapping; the tunnel was nearly completed, and the mapping was up to date. A brief report on the geology will be prepared.

"*New Almaden Quicksilver District.* With the support of the cooperative program during the first quarter of the year, the field work at New Almaden was completed in October 1947. A first draft of the report will be completed by December 1948.

"*Bishop Tungsten District.* Mapping of the general geology of two 15-minute quadrangles, the Bishop No. 2 and the Mt. Goddard No. 1, was completed on air photographs during the year, and the geology of a third, the Bishop No. 3, was started. A report was prepared on the Tungsten Hills deposits of the district, and is being reviewed prior to transmittal to the State for publication. New air photographs in the area were made available in August 1947, and at that time control for the new topographic base maps was started. It is unlikely, however, that the first of the new topographic sheets will be available before the spring of 1949.

"*Cerro Gordo-Ubehebe Lead-Zinc District.* The field work on the general geology of the two 15-minute quadrangles was two-thirds completed by the end of the year, and the detailed study of the Cerro Gordo mine was completed. New air photographs providing full coverage of the quadrangles became available in August 1947. The completion of mapping the general geology on air photographs and the study of minor mineralized areas will require most of another year. Control for the new topographic base maps was started in the spring of 1948; the new sheet of the Cerro Gordo quadrangle is scheduled to be available in manuscript form by the spring of 1949, and that for Ubehebe a few months later.

"*San Diego Pegmatite Districts.* Field work on the San Diego pegmatite districts was nearly completed during the year. A map of the general geology, scale 1:24,000, was completed for 150 square miles along the belt. All the new topographic base maps for this belt are scheduled to be available by the end of 1948. The pegmatite deposits of the principal group, the Pala group near the north end of the belt, were examined in great detail and a report on them was prepared. The detailed examinations of the smaller groups at Rincon and Mesa Grande are scheduled for completion in the first half of the next fiscal year, together with preparation of a final report on them and on the general geology.

"California Limestone Deposits

An investigation of the geology of California limestone deposits began in September 1947 but was discontinued after five months upon the resignation of the geologist assigned to the work. One deposit in the Klamath Mountains near Gazelle and one in the Sierra Nevada near Sonora were examined. Reports on them were prepared, and at the year's end these were in the process of review prior to transmittal for publication."

PUBLICATIONS

An increase of sales of publications of the Division of Mines occurred in the 99th fiscal year, as tabulated below:

	98th fiscal	*99th fiscal*	*Amount of increase*	*Percent increase*
Publication sales excluding subscriptions	$5,693.26	$7,086.38	$1,393.12	24%
Subscriptions	687.03	1,579.75	892.72	130%
TOTAL PUBLICATION SALES	$6,380.29	$8,666.13		
TOTAL AMOUNT OF INCREASE			$2,285.84	36%

The total publication sales for the 99th fiscal year represent an increase of nearly 36 percent over the 98th fiscal year. The increase in subscriptions above was 130 percent. This increase was due to (a) increased activity in the mineral industry, (b) increased activity of the Division of Mines, (c) improvement in the work of the Division, (d) distribution without cost of the monthly pamphlet ''Mineral Information Service'' to a mailing list of 4500, and (e) distribution without extra charge, to this same mailing list, of two small reprints (noted below) of general interest which proved to be a distinct stimulus to prospecting and exploration:

6000 copies of "Manner of Locating and Holding Mineral Claims in California"
4000 copies of "Mineral Industry of California in 1947"

During the 99th fiscal year, the quarterly issues of the *California Journal of Mines and Geology* were brought up to date. By June 30, 1948, copy for the July and October issues was in press, and six previous quarterlies were published and distributed to the public. This means that the work of two years was done in one.

In addition to these eight issues of the Journal, each issue of which contains four or five technical papers, the Division has submitted for publication eleven bulletins or parts of bulletins (129, 134, 136, 137, 139, 140, 141, 143, 144, 145, 146). Some of these reports represent large technical treatises; they include two annual statistical bulletins, the publication of which brings the Division up to date on this work.

The material included in these publications, as shown in the accompanying list of titles, covers a wide range of subjects: mineral commodity studies; mining law; topographic mapping; mineral resources of counties; physiographic features; quadrangle geology; subsurface studies in the oil fields; mineralogy; economics; statistics; techniques; and popular geologic guides.

Contributions from various sources have provided much material for this large publication program. In the following lists of reports, the contributing agency is indicated by letter-symbol as follows:

SDM—State Division of Mines
GS—U. S. Geological Survey
U—University departments
C—Other contributors
BM—U. S. Bureau of Mines

Reports Published

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 43, no. 1, January 1947.
- Walibu Quicksilver Mine, Kern County, California, by Edgar H. Bailey and C. Melvin Swinney (GS, strategic minerals investigation)
- Mines and Mineral Resources of Lake County, California, by Charles V. Averill (SDM)
- Mines and Mineral Resources of San Benito County, California, by Charles V. Averill (SDM)
- Condenser Installation at the New Idria Quicksilver Mining Company, Idria, California, by Richard A. Crippen Jr. (SDM)
- Information in Regard to Mining Claims on the Public Domain
- Mineral Patents

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 43, no. 2, April 1947.
- Mines and Mineral Resources of Stanislaus County, by Abbott Charles (SDM)
- Vanadium, by W. B. Winston (SDM)
- Fifty Years of Operation by The Mountain Copper Company, Ltd., in Shasta County, California, by William F. Kett (C)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 43, no. 3, July 1947.
- Status of Topographic Mapping in the United States, prepared by Map Information Office of the United States Geological Survey (GS)
- Limestone in California, by Clarence A. Logan (SDM)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 43, no. 4, October 1947.
- Annual Report, Division of Mines, for the Ninety-eighth Fiscal Year, July 1, 1946 to June 30, 1947, by Olaf P. Jenkins (SDM)
- Mines and Mineral Resources of Siskiyou County, by J. C. O'Brien (SDM)
- Silver, by W. B. Winston (SDM)
- Pumice, by W. B. Winston (SDM)
- Index to Volume 43

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 44, no. 1, January 1948.
- Trends in the Foundry-Sand Industry, by Leonard O. Hofstetter (C)
- Properties of Foundry-Sands, by Heinrich Ries (C)
- California Foundry Sands, by Lauren A. Wright (SDM)
- Uranium, by W. B. Winston (SDM)
- Manner of Locating and Holding Mineral Claims in California, by A. H. Ricketts and C. A. Logan (Reprinted)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 44, no. 2, April 1948.
- The Basement Complex in Well Samples from the Sacramento and San Joaquin Valleys, by J. C. May and R. L. Hewitt (C)
- Mines and Mineral Resources of Napa County, California, by Fenelon F. Davis (SDM)
- Soda Ash and Saltcake in California, by Clarence R. King (SDM)
- The Lakes of California, by William Morris Davis (Reprinted)

BULLETIN 129—IRON RESOURCES OF CALIFORNIA
- Part L—Iron-Ore Deposits Near Lake Hawley and Spencer Lakes, Sierra County, California, by Cordell Durrell and Paul D. Proctor (GS, strategic minerals investigation)
- Part M—Iron Deposits of the Kingston Range, San Bernardino County, California, by D. F. Hewett (GS, strategic minerals investigation)
- Part N—Summary of the Iron-Ore Situation in California, by Ernest F. Burchard (GS, strategic minerals investigation)
- Part O—Summary of Investigations of the Iron-Ore Deposits of California, by A. C. Johnson and Spangler Ricker (BM)

- Part P—Titaniferous Iron-Ore Deposits of the Western San Gabriel Mountains, Los Angeles County, California, by Gordon B. Oakeshott (C)
- Bibliography of the Iron-Ore Resources of California
- Index to Bulletin 129

BULLETIN 134—GEOLOGICAL INVESTIGATIONS OF CHROMITE IN CALIFORNIA

- Part I, Chapter 1—Chromite Deposits of Del Norte County, California, by Francis G. Wells, Fred W. Cater, Jr., and Garn A. Rynearson (GS, strategic minerals investigation)
- Part II, Chapter 1—Chromite Deposits of the Northern Coast Ranges of California, by D. H. Dow and T. P. Thayer (GS, strategic minerals investigation)
- Part III, Chapter 1—Chromite Deposits of Tuolumne and Mariposa Counties, California, by Fred W. Cater, Jr. (GS, strategic minerals investigation)
- Part III, Chapter 2—Chromite Deposits of Calaveras and Amador Counties, California, by Fred W. Cater, Jr. (GS, strategic minerals investigation)

BULLETIN 137—CALIFORNIA MINERAL PRODUCTION AND DIRECTORY OF MINERAL PRODUCERS FOR 1945, by Henry H. Symons (SDM)

BULLETIN 139—CALIFORNIA MINERAL PRODUCTION FOR 1946, by C. V. Averill, C. R. King, H. H. Symons, and F. F. Davis (SDM)

Reports in Press June 30, 1948

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 44, no. 3, July 1948.

- Unusual Concretions from Templeton, San Luis Obispo County, California, by R. A. Crippen Jr. (SDM)
- Quicksilver Deposits of the Guerneville District, Sonoma County, California, by W. Bradley Myers and Donald L. Everhart (GS, strategic minerals investigation)
- Mining Law in Recent Years, by William E. Colby (C)
- Pumice and Perlite as Industrial Materials in California, by Clarence R. King (SDM)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY, vol. 44, no. 4, October 1948.

- Some Economic Aspects of Mercury Production in California, by Clarence R. King (SDM)
- Current Mining Activity in the Redding District, by J. C. O'Brien (SDM)
- Development and Use of the Polarograph and Spectrograph, by John Herman (C)
- Public Resources Code
- U. S. Atomic Energy Commission Circulars 1-3
- Publications of the California State Division of Mines (SDM)
- Index to Volume 44

BULLETIN 134—GEOLOGICAL INVESTIGATIONS OF CHROMITE IN CALIFORNIA

- Part III, Chapter 3—Chromite Deposits of Tulare and Eastern Fresno Counties, by Garn A. Rynearson (GS, strategic minerals investigation)

BULLETIN 136—MINERALS OF CALIFORNIA, by Joseph Murdoch and R. W. Webb

BULLETIN 140—GEOLOGY OF THE TESLA QUADRANGLE, CALIFORNIA, by Arthur S. Huey (U)

BULLETIN 141—GEOLOGIC GUIDEBOOK ALONG HIGHWAY 49—SIERRAN GOLD BELT (THE MOTHER LODE COUNTRY)

- Preface, by Olaf P. Jenkins (SDM)
- Sierran Roads of Today and Yesterday, by Dorothy G. Jenkins (C)
- The "Discovery" of Gold in California, by Donald C. Cutter (U)
- History of Placer Mining in California, by C. V. Averill (SDM)
- The Sierra Nevada Province, by Olaf P. Jenkins (SDM)
- Geologic History of the Northern Sierra Nevada, by Olaf P. Jenkins (SDM)
- Development of Mining and Milling Methods in California, by C. A. Logan (SDM)
- Geologic Log Along Highway 49, by Oliver E. Bowen and Richard A. Crippen Jr. (SDM)
- Mining on Carson Hill, by John A. Burgess (C)
- The Formation of Quartz Veins, by John A. Burgess (C)
- Survey of Building Structures of the Sierran Gold Belt, by Robert F. Heizer and F. Fenenga (U)

BULLETIN 143—Geologic Map of Hollister Quadrangle, by N. L. Taliaferro (U)

BULLETIN 144—COPPER IN CALIFORNIA

- Foothill Copper-Zinc Belt of the Sierra Nevada, California, by George R. Heyl (GS, strategic minerals investigation)
- Zinc-Copper Deposits of the Big Bend Mine, Butte County, California, by John H. Eric (GS)
- Geology of the Lilyama and Pioneer Mines, El Dorado County, California, by Manning W. Cox, Donald G. Wyant, and George R. Heyl (GS)
- Newton Copper Mine, Amador County, California, by George R. Heyl and John H. Eric (GS)
- Penn Copper-Zinc Mine, Calaveras County, California, by George R. Heyl, Manning W. Cox, and John H. Eric (GS)
- Grayhouse Area, Amador County, California, by George R. Heyl (GS)
- Ore Deposits of Copperopolis, Calaveras County, California, by George R. Heyl (GS)
- The Zinc-Copper Mines of the Quail Hill Area, Calaveras County, California, by George R. Heyl (GS)
- La Victoria Copper Mine, Mariposa County, California, by Manning W. Cox and Donald G. Wyant (GS)
- Zinc Deposits of the American Eagle-Blue Moon Area, Mariposa County, California, by John H. Eric and Manning W. Cox (GS)
- The Jesse Belle Copper Mine, Madera County, California, by Manning W. Cox and Donald G. Wyant (GS)
- The Marketing and Metallurgy of Complex Ores, by Hadley R. Bramel (U)
- Tabulation of Copper Deposits of California, by John H. Eric (GS)
- Bibliography

BULLETIN 145—Geologic Map of Copperopolis Quadrangle, by N. L. Taliaferro (U)

BULLETIN 146—Geologic Map of Lake Elsinore Quadrangle, by Renee Engel (C)

Reports Available for Processing for Publication
June 30, 1948

Quicksilver Deposits of the Oakville District, Napa and Sonoma Counties, California, by Philip F. Fix and C. Melvin Swinney (GS, strategic minerals investigation)
Barium, by W. B. Winston (SDM)
Mines and Mineral Resources of Tuolumne County, by C. A. Logan (SDM)
Geology of Quien Sabe Quadrangle, California, by C. J. Leith (U)
Geology of Blue Lake Quadrangle, California, by B. A. Ogle and George A. Manning (U)

DISTRICT OFFICES

The Division of Mines maintains three district offices for the purpose of keeping in closer touch with mining operations and mineral industries than is possible from the headquarters in San Francisco alone. Of the three—Los Angeles, Sacramento, and Redding—the Los Angeles district office receives the largest number of requests for technical information and serves the largest area. This district contains a huge market for the state's raw minerals, especially those used in chemical, structural, and ceramic industries. In the Los Angeles office over 15,000 individual services were rendered during the 99th fiscal year by correspondence, oral interviews, and telephone; in Sacramento 2700; in Redding 1500. This service relieves the headquarters office in San Francisco, which answers approximately 16,000 written inquiries and gives about 12,000 oral interviews per year, not including telephone calls which amount to an additional 19,000. The increasing activities of the Los Angeles office, 15 percent over the 98th fiscal year, have made it necessary to increase the staff and to supply it with a small working library and collection of minerals. Because of its proximity to large educational institutions, the Los Angeles office has been able to keep in close contact with the research workers in those institutions and with cooperative field projects with the federal Geological Survey which are being conducted in southern California. An economic study of mineral markets has been started in the Los Angeles area similar to that which is under way in the San Francisco Bay area.

Publications are sold in the Los Angeles and Sacramento offices as well as in the headquarters office in the Ferry Building, San Francisco. Total sales excluding subscriptions (amounting to $1,579.75) in San Francisco for the 99th fiscal year were $7,086.38; in Los Angeles $1,452.80; and in Sacramento $448.95. Publications are not sold in the Redding office.

Preparation of county reports on mining activities is an important function of the district offices. During the 99th fiscal year the following county reports were in preparation in these offices: Los Angeles office, Kern and Inyo Counties; Sacramento office, Tuolumne County; and Redding office, Siskiyou County. The San Francisco office had in preparation during the 99th fiscal a report on Alameda County and started a report on Sonoma County.

All district offices contributed to the general summaries of commodities and counties required in the annual report of the Division.

Addresses of the district offices are as follows:

Los Angeles District Office: 217 W First Street (State Building) Room 402B, Zone 12. Telephone: MAdison 1271.
Sacramento District Office: 631 J Street, Room 300, Zone 14. Telephone: 24711, Ext. 631.
Redding District Office: 1739 Yuba Street (Oaks Building), P. O. Box 445, Redding. Telephone: 1168M.

The Redding office is shared with the U. S. Geological Survey, a section of the federal agency which is working in cooperation with the State Division of Mines.

ORE BUYERS' INSPECTION

The activities of Ore Buyers' Inspection during the 99th fiscal year have increased over the previous year. There was only a slight increase in the number of licenses issued. During the calendar year 1947, 50 limited and 43 unlimited licenses were issued. For the calendar year 1948 to date there have been 49 limited licenses and 50 unlimited. A decided increase in the number of inquiries regarding gold licenses has been observed, probably because of the ruling of the U. S. Treasury Department that gold in its native state may be sold and held under the provisions of the Gold Reserve Act of 1934. Some sales of gold in its natural state have been made at $50.00 an ounce. Owing to this revived interest in gold a decided increase in the activities of the Ore Buyers' Inspection is expected for the 100th fiscal year.

During the 99th fiscal year, 347 contacts were made and 33 cases investigated, which resulted in six arrests and one conviction. With this one exception, persons arrested were released by the federal court, but the gold involved was confiscated. Gold in the amount of $7,400 was libeled and seized and turned over to the United States Treasury. Gold in the amount of $1,200 was returned to the owner from whom it was stolen. The sum of $233.52 was turned over to the State Treasury from the sale of gold which has escheated to the state.

PLANS FOR 100TH FISCAL YEAR

A large backlog of projects under way, reports in preparation, and maps nearly completed will provide material for the major activities of the Division of Mines during the 100th fiscal year. The new work falls into the following programs.

(a) Statewide basic geologic mapping
(b) Statewide commodity survey
(c) Inventory of mining activities by counties
(d) Mineral information service to the public

It will be necessary to give more attention to the development of mineral fuel resources and to help new industries find sources for the desired raw mineral materials. A market or mineral utilization survey must be conducted in both the San Francisco Bay area and in the Los Angeles area. Preparation of another geologic guidebook will probably be started to cover a long strip of territory 600 miles in length following the rift zone of the San Andreas fault, a major feature in the world as well as in the state concerning which innumerable questions are asked the State Division of Mines. A general feature story could be written in connection with this guidebook which would give the layman a general knowledge of the geology and mineral resources of the entire coastal area of California.

QUICKSILVER DEPOSITS OF THE OAKVILLE DISTRICT, NAPA COUNTY, CALIFORNIA*

BY PHILIP F. FIX ** AND C. MELVIN SWINNEY **

OUTLINE OF REPORT

Page
Abstract ---- 31
Introduction ---- 32
Geography ---- 33
History of the Oakville district ---- 33
Geology ---- 34
    Sedimentary rocks ---- 35
    Serpentine ---- 35
    Sonoma volcanics ---- 35
    Silica-carbonate rock ---- 35
    Geologic structure ---- 37
Quicksilver deposits ---- 37
    Minerals ---- 37
    Structural control of ore deposits ---- 37
    Size and grade of ore bodies ---- 38
Suggestions for prospecting in the Oakville district ---- 38
Reserves ---- 39
Mines and prospects ---- 39
    La Joya mine ---- 39
        History ---- 39
        Geology ---- 41
        Suggestions for further exploration ---- 42
    Bella Oak mine ---- 43
        History ---- 43
        Geology ---- 44
        Suggestions for further exploration ---- 46
    Prospects ---- 46

Illustrations

Figure 1. Index map showing location of Oakville quicksilver mining district ---- 32
2. The Oakville quicksilver mining district ---- 36
Plate 1. Geologic map of La Joya Mine ---- In pocket
2. Underground workings of La Joya mine ---- In pocket
3. Geologic map of the Bella Oak mine ---- In pocket

ABSTRACT

The Oakville quicksilver mining district in the Coast Ranges 40 miles north of San Francisco has a recorded yield of 3,809 flasks of quicksilver from La Joya and Bella Oak mines.

Conglomeratic sandstone and shale of the Jurassic (?) Franciscan (?) group have been thrust over black shale of the Jurassic-Cretaceous (?) Knoxville (?) formation on the southwestward-dipping Bella Oak thrust fault. Late Mesozoic (?) serpentine occurs in a number of faults. The Sonoma volcanics of Pliocene and Pleistocene age cap the higher divides.

Cinnabar has been found chiefly in veinlets with chalcedony and quartz in relatively thick bodies of brecciated hydrothermally altered serpentine known as silica-carbonate rock, which also contains pyrite and a chromian member of the montmorillonite group. All known ore bodies were found in structural troughs and pockets along the faulted margins of serpentine bodies, or where dips of hanging walls of faults were greatly lessened by sharp rolls.

Visible ore reserves in accessible workings were nil when the mines were visited, and most of the underground workings were inaccessible. The deepest workings of

---

* Published by permission of the Director, U. S. Department of the Interior, Geological Survey. Manuscript received for publication July 29, 1948.

** Geologist, U. S. Geological Survey.

La Joya and Bella Oak mines are said to be, respectively, about 350 and 250 feet down the dip from outcrops. The district seems to offer little promise under ordinary conditions, but under unusually favorable economic conditions may yield additional quicksilver.

INTRODUCTION

La Joya (Spanish, *the jewel)* and Bella Oak (Spanish, *bella, beautiful)* mines were mapped by the authors in May and early June 1943 as part of the Strategic Minerals Investigations of the Geological Survey, but only a few days were available for a reconnaissance of the district. Additions to the map of the Bella Oak mine were made periodically until mining ceased in August 1943. In the spring of 1945, Philip F. Fix investigated the history of the district in available literature, and made a petrographic study of thin-sections of rocks and vein minerals collected by him in 1943.

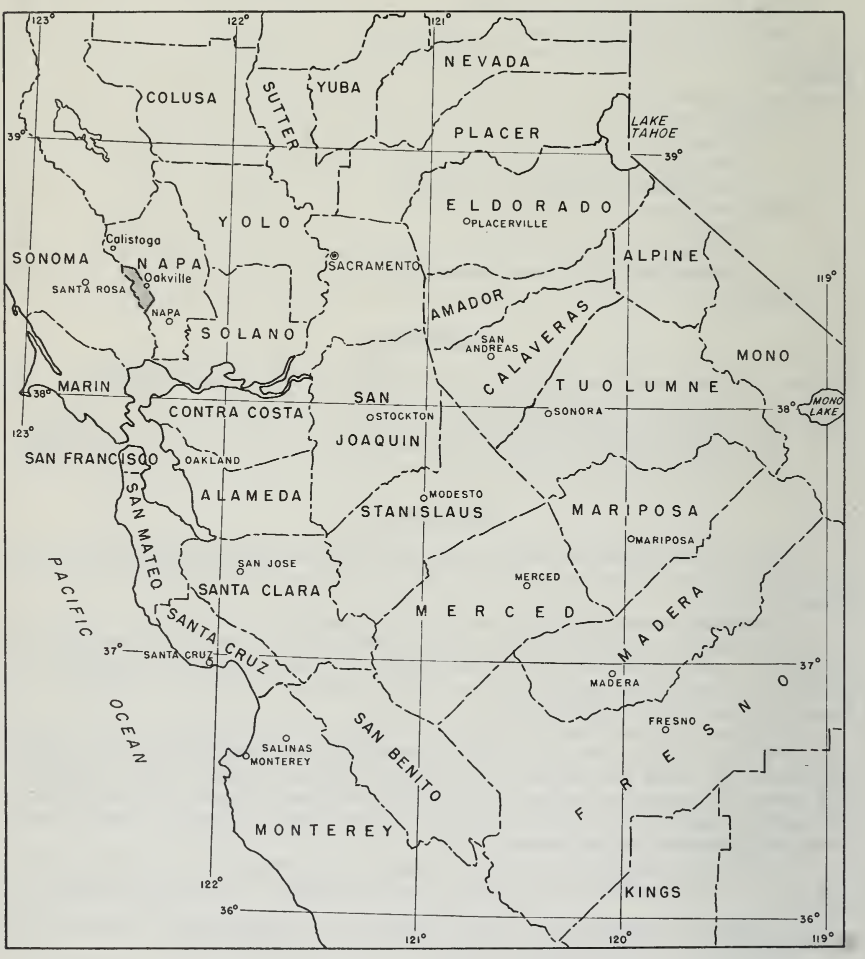


FIGURE 1. Index map showing location of the Oakville quicksilver district, Napa County, California

The base map of the district (fig. 2) was compiled from topographic maps of the Calistoga, Santa Rosa, Napa, and St. Helena quadrangles of the Geological Survey. Airphotos of part of the Cache and Putah Creeks project of the Department of Agriculture were used in the reconnaissance. The plane table maps of the two mines were made on scales of 200 and 100 feet per inch, respectively, and underground workings were mapped on a scale of 50 feet per inch.

The authors are grateful to Edwin B. Eckel, who was directing the quicksilver investigations of the Geological Survey in 1943, for suggestions concerning the field work that contributed to this report. Helpful information was furnished by a number of persons, but special acknowledgment is due Fred A. Bachich of St. Helena, who was operating the mines in 1943; H. W. Gould and Company of San Francisco, for information and available maps; and the *Weekly Calistogan* of Calistoga and the *St. Helena Star* of St. Helena for access to their files.

This report was written, and the maps were drafted by Philip F. Fix. The writer is grateful to N. D. Stearns, Edgar H. Bailey, Juanita Crawford, and M. D. Crittenden of the Geological Survey for many helpful suggestions during the preparation of the report. C. Melvin Swinney was transferred to Alaska in June 1944, and was on military furlough from the Geological Survey at the time the report was prepared.

GEOGRAPHY

The Oakville quicksilver mining district (fig. 1) is 40 miles north of San Francisco, and as herein limited consists of about 50 square miles of the rugged Miyakma Range of the northern California Coast Ranges. With the exception of a few square miles in Sonoma County west of the divide, the district lies in Napa County on the eastern slope extending from the divide eastward to Napa Valley. Altitudes range from 100 feet above sea level at the edge of the foothills half a mile west of Yountville, to 2,717 feet above sea level on the highest mountain peak. Dense brush and scattered timber cover most of the district, and many geologic details are concealed by landslides, residual soil, and alluvium.

HISTORY OF THE OAKVILLE DISTRICT

The recorded yield of the Oakville district is 3,809 flasks of quicksilver believed to have been sold for about $365,000 (table 1). Of this total, 2,017 flasks came from La Joya mine, whose largest annual output was 877 flasks in 1929, and 1,792 flasks came from the Bella Oak mine. The total unrecorded yield of the district is believed to have been very small. Cinnabar probably was first discovered in the district during the prospecting rush of 1860. The Summit mine that apparently later became part of La Joya mine was located in 1865.[1] The Oakville and Bella Union claims that later were consolidated into the Bella Union mine, and finally became the Bella Oak mine, were located in 1868.[2]

---

[1] Napa County, California, Miscellaneous Records, vol. B, p. 307.

[2] Napa County, California, Patents, vol. B, pp. 274-76.
Idem, Mining Deeds, vol. 1, p. 33.
Palmer, Lyman L., History of Napa and Lake Counties, California, p. 169, San Francisco, Slocum, Bowen, and Co., 1881.

Table 1. Recorded production of quicksilver, Oakville district, California.[1]

Year	Mines		Oakville district		
	La Joya	Bella Oak	Total[2]	Period sub-totals	
	Flasks[3]	Flasks	Flasks	Flasks	Value[4]
1872	----------	[5]201	201		
1873	[6]75	[5]199	274		
1876	----------	271	271	746	$47,175
1915	25	----------	25		
1916	51	114	165		
1917	329	128	457		
1918	139	53	192		
1919	----------	4	4		
1920	----------	4	4	847	84,935
1928	123	----------	123		
1929	877	55	932		
1930	147	395	542		
1931	53	341	394		
1932	72	10	82		
1933	88	----------	88		
1934	1	----------	1	2,162	226,270
1938	12	----------	12		
1939	25	----------	25		
1942	----------	12	12		
1943	----------	5	5	54	6,500
	[7]2,017	[8]1,792	3,809		$364,880

[1] From records of the California Division of Mines unless otherwise stated.

[2] No record of production from any other mine or prospect.

[3] A flask contained 76½ pounds of quicksilver before June 1904; 75 pounds from June 1904 to June 1927; and 76 pounds thereafter.

[4] Estimated approximate value computed from average price for each year; 1872-1936 prices are from tables 1 and 2 by A. L. Ransome and J. L. Kellogg. Quicksilver resources of California, "California Journal of Mines and Geology," October 1939.

[5] Total recorded production for 1872-73 "about 400 flasks" (W. W. Bradley, California Min. Bur. Bull. 78, p. 80, 1918). Rossiter W. Raymond (Statistics of mines and mining in the states and territories west of the Rocky Mountains for 1873, p. 30, 1874) said the Oakville mine produced 180 flasks between June 21 and December 31, 1872, and 199 flasks from January 1, 1873 until the mine became bankrupt June 1, 1873. "Mining and Scientific Press" under dates of March 2 and April 20, 1872 said the Oakville mine was producing 400 pounds of quicksilver per day beginning in February. Therefore, it appears that the Bella Oak mine, of which the Oakville claim is part, yielded 201 flasks of record in 1872 plus an unknown amount not recorded.

[6] Raymond, Rossiter W., op. cit. p. 30. Credited to Summit mine, apparently included in present La Joya mine.

[7] Estimated to have been sold for about $211,500.

[8] Estimated to have been sold for about $153,380.

GEOLOGY

Mesozoic sedimentary rocks of the Franciscan (?) group and the Knoxville (?) formation make up most of the Oakville district, but the higher divides are capped by the Sonoma volcanics of Pliocene and Pleistocene age. The principal folds and faults strike northwest in harmony with the geologic structure of the northern California Coast Ranges. The principal fault of the district is the Bella Oak thrust fault that strikes N. 45° W. and dips 10° to 35° SW., on which rocks of the Franciscan (?) group have been thrust over the Knoxville (?) formation.

Mesozoic (?) serpentinized ultramafic igneous rocks in tabular to irregular pipe-like bodies occupy many of the faults and some sheared bedding planes. The largest bodies are several miles long; 50 to 200 feet thick at the outcrop; strike northwest; and dip southwest. Silica-carbonate rock formed by the hydrothermal alteration of serpentine along the most favorable structural channels contained all of the quicksilver ore bodies known to have been mined in the district.

Sedimentary Rocks

The oldest known rocks of the Oakville district are conglomeratic sandstone and shale of the Franciscan (?) group, generally supposed to be of Jurassic age, whose apparent thickness is several thousand feet. These rocks are well exposed on the headwaters of Dry Creek in the vicinity of La Joya mine.

Black shale of the Knoxville (?) formation, generally supposed to be of Jurassic and Cretaceous age, crops out in the southeastern part of the district, and is particularly well exposed along the Oakville-Glen Ellyn road east of Dry Creek. The apparent thickness of several thousand feet is unreliable because of the presence of many distorted folds and faults. Several specimens of *Aucella sp.* ranging from 1 to 2 inches in diameter were found in the black shale footwall of the Bella Oak thrust fault in the Bachich 1943 inclined shaft of the Bella Oak mine. (pl. 3)

Serpentine

Serpentine formed by the alteration of ultramafic intrusive rocks is relatively abundant, and, although no criteria of age determination were found in the district, the geologic age is generally supposed to be Jurassic or Cretaceous. The fresh rock is bluish-green to dark green, but weathered surfaces commonly have rusty red mingled with the green. The color grades into gray-green and gray where considerable carbonate is present, as in parts of La Joya mine. Most of the rock is badly sheared, but some retains traces of original igneous textures. The serpentine weathers into soils inhospitable to plants, hence the outcrops can be recognized by their color and scanty vegetation.

Sonoma Volcanics

The Sonoma volcanics, generally believed to be Pliocene and Pleistocene in age, consist of lava flows and fragmental volcanic rocks whose total thickness in the district may be several thousand feet. They were deposited on an old erosion surface, hence they now cap most of the interstream divides at higher altitudes. They also crop out in some places, particularly west of Yountville, in the sides and floors of creek valleys in circumstances suggesting that either the erosion surface was warped later, or that they were deposited in what at the time were major stream valleys. Most of the Sonoma volcanics are hydrothermally altered and light colored, but some are red, black, or gray, and are little altered. Their soil generally supports a dense growth of trees and brush.

Silica-Carbonate Rock

Silica-carbonate rock, the host rock of all known quicksilver ore bodies of the district, consists of quartz, chalcedony, and mixed carbonate formed by the intensive hydrothermal alteration of serpentine. The rock of the deeper underground workings is light gray to cream colored, contains some pyrite, and much of it is spotted by a bluish-green chromian member of the montmorillonite group. The rock is yellowish-brown at and near the surface; the more siliceous phases crop out as bold, rusty ledges, and the less siliceous phases weather to an ocherous soil readily recognized by its color. Some outcrops support a dense growth of brush

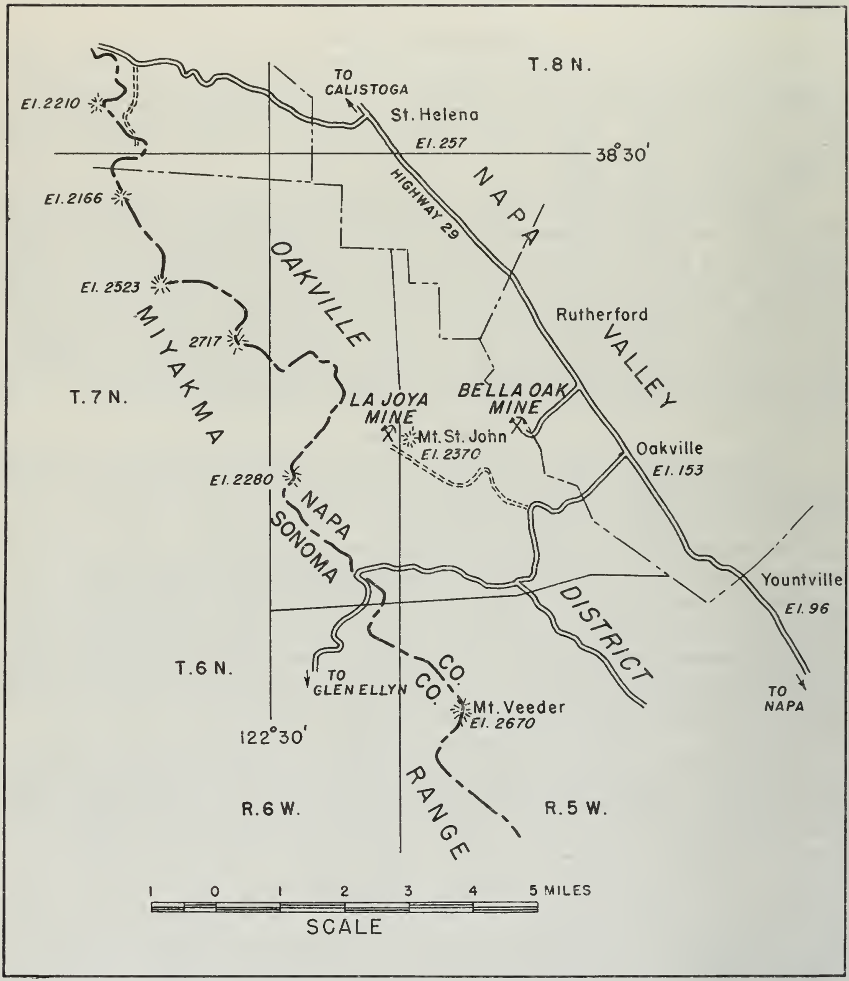


FIGURE 2. The Oakville quicksilver district, Napa County, California

and trees. The age of the rock is known only as post-serpentine and probably pre-Sonoma. The rock at some relatively late date was fractured intensively, and the fractures were filled with veinlets of quartz and chalcedony that contain cinnabar where conditions were suitable.

Geologic Structure

The rocks of the Franciscan (?) group in general strike N. 50° W., and dip 20° to 70° SW., but there are many local irregularities. The strike of the Knoxville (?) formation seems to be northwesterly, and the dip is 20° to 35° SW. in the Bella Oak mine; most of the outcrops are distorted by many small folds and faults. The principal shear zones and faults strike northwestward, and the dips range from 10° SW. to vertical. The principal faults are occupied by serpentine, hence their age presumably is pre-serpentine. Some faults not occupied by serpentine may be considerably younger, but no post-cinnabar displacement was found.

The principal fault of the district is the Bella Oak thrust fault, on which it is believed that rocks of the Franciscan (?) group have been thrust over the Knoxville (?) formation. The fault was traced about 3,600 feet in the Bella Oak mine and vicinity, where it strikes N. 45° W. and dips 10° to 35° SW. except where rolls locally reverse the dip to northeast. The strike may swing sharply toward the west not far south of the mine, because the black shale of the Knoxville (?) formation along La Joya mine road half a mile from the Oakville-Glen Ellyn road (fig. 2) and 1 mile southwest of the Bella Oak mine crops out about 500 feet higher than in that mine. Striations on the thick black gouge in the mine suggest an oblique slip with a large dip-slip component.

The authors are convinced it is an important thrust fault, but the unsatisfactory state of knowledge concerning the Mesozoic rocks of northern California does not rule out the possibility that the rocks in the Oakville district identified on the basis of lithology as Franciscan (?) group might be in their normal stratigraphic position above the Knoxville (?) formation, if the two should be facies of one sequence, although separated by the thrust fault approximately parallel to the bedding.

QUICKSILVER DEPOSITS

Minerals

Cinnabar is the ore mineral of La Joya and Bella Oak mines, and, chiefly as the finely divided variety known as ''paint,'' is said to have been found in several prospects. Native mercury was not seen. Cinnabar in the two mines is chiefly in veinlets of chalcedony and quartz; in La Joya mine small amounts of a solid black hydrocarbon with a brown streak were seen in quartz-lined vugs in these veinlets in a few places. Considerable pyrite is found in the silica-carbonate rock of both mines.

Structural Control of Ore Deposits

The position of the mines in the district was determined by the principal structural troughs or channels along the major faults through which the mercury-bearing solutions rose; these seem to be the same channels along which hydrothermal solutions had risen long before to form the most important bodies of silica-carbonate rock from serpentine. The position of ore bodies in turn was determined locally by the distributary structural troughs that conducted the mercury-bearing solutions to bodies of host rock that could furnish the necessary environment for deposition of cinnabar. This environment was provided by bodies of silica-carbonate rock of adequate thickness, volume, and degree of brecciation where the solutions were slowed or stagnated by abrupt changes in the dip and strike of the faulted margins of the serpentine bodies where the silica-carbonate rock had been formed. Fault gouge and shale played an important role in guiding and blocking movement of the solutions.

Most structural features of this general type merely succeeded in trapping small amounts of cinnabar or none at all because they were not *unusually* efficient traps in *unusually* strategic places.

Size and Grade of Ore Bodies

The largest and richest group of closely spaced ''pods'' of ore separated by low-grade or barren material is said to have been found in the westward-plunging structural trough that crops out 1,100 feet northeast of the portal of No. 3 adit in La Joya mine (pls. 1 and 2) ; available scanty information suggests that perhaps as much as 45 percent of the quicksilver yielded by the district may have come from this trough. The stopes apparently occupied an area measuring horizontally 5 to 36 feet wide by 125 to 175 feet long that extended an inclined distance of about 300 feet from somewhere near the No. 3 (1636) level to an unknown distance above the No. 2 (1793) level, where they connected with the 1910-level shaft.

The second most productive group of ''pods'' of ore is believed to have been found in the North workings of the Bella Oak mine (pl. 3, section A-B), but little tangible information was obtained concerning the relative amounts of quicksilver yielded by the three main groups of workings of that mine.

Other ore bodies found in the district are believed to have been small and mostly of low grade. The size and shape of stopes afford no proof of the amount of quicksilver obtained because the deposits in many places consisted of small swarms of cinnabar-chalcedony-quartz veinlets scattered among wide zones of barren or low-grade rock.

SUGGESTIONS FOR PROSPECTING IN THE OAKVILLE DISTRICT

The geologic conditions under which ore bodies have been found in La Joya and Bella Oak mines are guides for further exploration, but the possibility of ore bodies occurring under somewhat different conditions should not be overlooked.

The most effective method of search would be detailed geologic mapping of that part of the district that contains the two mines, and preferably of the entire district, to provide the data for three-dimensional analysis of the geologic structure to seek troughs or other structural features of such shape and strategic position that they were capable of trapping quicksilver; if any should be found, one may then determine by the methods customary in the quicksilver-mining industry whether or not they actually did form ore. Exploratory drilling is a very useful method of determining in advance the position and attitude of bodies of silica-carbonate rock, and working out other geologic details, but it cannot entirely replace underground mining exploration because the small size and very irregular nature of quicksilver ore bodies make very slight the chance of scoring a direct hit on a ''pod'' of ore with the drill.

Search may be divided into three phases: (1) continued search in the known major structural troughs of the two mines for possible additional ore bodies; (2) search for other possible major structural troughs or channels in the district that may have been overlooked or deemed inconsequential in the past as the result of inadequate geologic study; and (3) search for minor channels that might have trapped "pods" of ore so small that their contents would be of negligible importance.

Some quicksilver deposits may perhaps exist in silica-carbonate rock buried under Sonoma volcanics, but there is no known way to search for such possible deposits effectively, nor even for the host rock, at the present time.

Further suggestions applicable to each mine are given in the discussions of the individual mines.

RESERVES

Visible reserves of quicksilver ore in the accessible workings in the district were nil, as they are so often in most quicksilver mines. The small size of the average "pod" of quicksilver ore, usually discovered at the cost of much time and money, results in its being mined out shortly after discovery. With each discovery, one seldom knows whether the last "pod" had been found. Each time that the relationship between the price of quicksilver and the cost of production became extraordinarily favorable, the mines were reopened and exploration was resumed (see table 1 and the history of each mine). There seems no reason to believe that the present lack of known reserves marks the exhaustion of the district.

MINES AND PROSPECTS

La Joya Mine

La Joya mine, which apparently includes what in the seventies was known as the Summit or Whitton mine, is in section 24, T. 7 N., R. 6 W., M. D., on the divide between Napa Valley and the head of Dry Creek (fig. 2 and pl. 1). The mine is 3½ miles airline and 7 miles by road west of Oakville, and 2 miles west of the Bella Oak mine. The property consists of 11 mining claims in section 24: the Occident, Globe, Eagle, Pacific, Star, Alta, Wedge, Iroquois, Columbia, Wedge Extension, and Comanche claims, totaling 184.58 acres, plus the mining rights on 480 acres of agricultural ground in sections 23 and 24.[4]

The recorded yield of the mine (table 1) is 2,017 flasks of quicksilver. The underground workings, including six shafts and three principal adits, are said to total more than one mile (pls. 1 and 2). The main haulageway, No. 3 adit, is said to be about 820 feet long, with workings about 900 feet along the strike of the silica-carbonate rock. Only 1,100 feet of workings were accessible in 1943; the principal stoped areas were inaccessible.

History. The old 1,000 by 2,400-foot Summit claim was located March 27, 1865 by M. S. Whitton, C. I. Whitton, R. I. Whitton, I. M. Whitton, W. T. Whitton, W. H. Whitton, and F. I. (?) Corning of Yountville, apparently on the summit of the mountain ridge that extends northwest from Mount St. John, ". . . beginning . . . near the gap of the mountain thence northwest to some pine trees near the summit of the mountain . . .".[5] The 1876 Official Map of Napa County shows the property of the Summit Mining Company chiefly in the NE¼ of section 24,[6] which seems to fit the above description. Crawford also gave the location of the Summit mine as section 24 at the head of Dry Creek.[7]

---

[4] H. W. Gould and Company, personal communication.
[5] Napa County, California, Misc. Records, vol. B, p. 307.

The Whitton brothers worked the Summit mine until they sold it to John Pershbaker for $45,000 in August 1872. They mined ore said to have ranged from 1 to 2½ percent Hg, and hauled it one mile on mules to their retort, whose capacity was 1½ tons per 24 hours.[8] In July 1871, the mine had a 450-foot adit that cut an ore body 70 feet thick (probably at an oblique angle), and connected with a 145-foot shaft 400 feet from the portal.[9]

Menafee described the Summit mine in 1873 as having three main adits with seven branches, and a main haulage level 400 feet long. The lowest workings were 165 feet below the surface, and had a steam pump in a winze 50 feet below the main haulage adit. A furnace that was charged hourly, and whose capacity was 24 tons per 24 hours, had been built on the site of the Whitton retort. A new wagon road one mile long had been built to connect mine and furnace. The scale of operations was indicated by the fact that 22 white men and 8 Chinese were employed.[10] The road referred to apparently is the abandoned road from the mine eastward along the north side of Mount St. John. The main haulage adit probably was the No. 2 adit of La Joya mine (pl. 1), and the shaft probably was one of the three above the No. 2-level stope.

Bancroft[11] said the mine was being operated in 1881 with a 24-ton furnace, but the later history of the old Summit mine is not known. Crawford[12] said in 1894 that an adit intended to reach the northwesterly striking vein 300 feet below the surface had been driven 250 feet at an unspecified date, but that was less than half the required length. This adit apparently is the present No. 3 of La Joya mine (pl. 1).

La Joya mine (apparently including what had been known as the old Summit mine of Whitton brothers) was opened in 1898 by the Standard Quicksilver Company, then operating the Mirabel quicksilver mine in Lake County.[13] Rich ore was reported found late in 1898, and a road to connect the mine with the Oakville-Glen Ellyn road was begun.[14] When Forstner[15] visited the mine, which he said had three known ore bodies and an unused 20-ton Fitzgerald furnace, the workings were caved and had been idle for some time.

The mine was acquired in 1915 by James Rennie, and operated under lease from 1915 to 1919 by the West Coast Investment Company.[16] In the spring of 1917, the old Fitzgerald furnace was yielding 1 flask of quicksilver per day from 6 tons of ore. A 12-pipe Johnson-McKay retort and a 20-ton Livingston furnace were built in 1917; the furnace proved unsuccessful, however. In 1918, the No. 3 adit was 820 feet long, and had a drift 400 feet along the principal vein, which averaged 6 feet in thickness except in the Big Stope where it was 36 feet thick. A smaller vein was in the hanging wall.[17]

---

[6] Lyman, George G., and Throckmorton, S. R., Official map of Napa County, California, August 12, 1876. (Made under contract dated March 12, 1873). Published by David L. Haas, Napa City and St. Helena, California, 1876.

[7] Crawford, J. J. Twelfth report of the State Mineralogist (second biennial): California Min. Bur. Rept. 12, p. 365, 1894.

[8] Menafee, C. A. Historical and descriptive sketch book of Napa, Sonoma, Lake, and Mendocino Counties, California, pp. 99-100, Napa City, Reporter Publishing House, 1873.

[9] Mining and Scientific Press, July 29, 1871, p. 56.

[10] Menafee, C. A., op. cit., pp. 99-100.

[11] Bancroft, H. H. History of California, vol. 7, p. 657, 1890.

[12] Crawford, J. J., op. cit., p. 365.

[13] Ransome, A. L., and Kellogg, J. L. Quicksilver resources of California: California Jour. Mines and Geology, vol. 35, p. 410, 1939.

[14] Weekly Calistogian, Calistoga, California, January 13, 1899.

[15] Forstner, William. The quicksilver resources of California: California Min. Bur. Bull. 27, p. 80, 1903.

[16] Ransome and Kellogg, op. cit., p. 410.

H. W. Gould and Company purchased the mine in 1926,[18] and leased it to Acme Mines and Mill, Inc., which installed a 3- by 40-foot rotary furnace in 1928 [19] and operated the mine until 1931.[20] The Lucky Strike Mining company worked under a sub-lease in 1930, and under lease from 1931 to 1934.[21] The property later was leased to others. About 1935 the mine became property of Oat Hill Mine, Inc., and about 1942 or 1943 the property of H. W. Gould and R. A. Hanan. Fred A. Bachich and T. C. Mellersh leased the mine and moved the rotary furnace to the Bella Oak mine in 1942,[22] but their attempt to reopen No. 3 adit failed in 1943 at a caved shaly zone 575 feet from the portal.

Geology. All known ore bodies of La Joya mine were found in brecciated silica-carbonate rock along the sheared and faulted contacts of serpentine with sandstone and shale of the Franciscan (?) group that strike N. 50° W., and dip steeply southwest in most places (pl. 1).

The principal mine workings are along the northwest margin of an irregular, apparently pipe-shaped body of serpentine 1,500 feet in diameter (southeast edge of map, pl. 1) that seems to represent an intrusive center from which approximately tabular arms of serpentine branch northwestward along the strike of the sedimentary rocks, and dip southwestward more or less parallel with their bedding. Arms of serpentine branch southeastward along the strike of the sedimentary rocks also, but outside of the map area.

The principal known structural channel of the mine is the westward-plunging trough that crops out 1,100 feet northeast of the portal of No. 3 adit, and forms a narrow, deep pocket filled with brecciated silica-carbonate rock in an unusually sharp re-entrant angle in the margin of the serpentine body. The general characteristics of this trough are evident from the surface geology and the maps of the inaccessible underground workings that are reported to extend about 350 feet down the dip; most of the details are unknown. The importance of this pocket is shown by the fact that it is reported that most of the 2,017 flasks of quicksilver yielded by the mine came from it, and that rich impregnations of cinnabar in the host rock are said to have been found in the richest part of the deposit in addition to the usual veinlets of cinnabar, quartz, and chalcedony.

It is believed that relatively small amounts of the quicksilver-bearing solutions ascending the main trough moved upward toward the northwest to form the small ore bodies said to have been found in the No. 1 and 1851 adits (pls. 1 and 2). A steeply plunging inverted trough in the serpentine hanging wall controlled deposition of the ore in brecciated silica-carbonate rock in the 1851 adit, the bottom of whose stope is on the 1793 (No. 2) level. Deposition of ore in the stope of No. 1 adit 350 feet southeast of the 1851 adit probably was controlled by a similar trough or roll. The geology in the inaccessible workings on the No. 3 level below the 1851 and No. 1 adits was not learned, but it is said that the northwest drift on the No. 3 level encountered silica-carbonate rock on both sides of serpentine.

---

[17] Bradley, W. W. Quicksilver resources of California: California Min. Bur. Bull. 78, p. 84, 1918.

[18] H. W. Gould and Company, personal communication.

[19] Tyler, P. M. Mercury: Mineral Resources U. S. 1928, pt. 1, p. 269, 1929.

[20] Ransome and Kellogg, op. cit., p. 410.

[21] Ransome and Kellogg, op. cit., p. 410.

[22] H. W. Gould and Company, personal communication.

A tabular body of silica-carbonate rock 700 feet long and several yards thick crops out in the northwest corner of the map area (pl. 1) with an apparent dip of about 60° toward the main body of serpentine 1,800 feet to the southeast. No serpentine was seen on the surface or in the north adit of the 1846 (No. 1) level, in which a few flasks of quicksilver are said to have been obtained from a shallow winze in brecciated silica-carbonate rock close to the sandstone hanging wall of the faulted contact. It is believed that this cinnabar may have been an outlying body genetically related to the ore of the main structural trough of the mine.

A structural trough of unknown attitude at the northwest corner of the main serpentine body 500 feet southeast of the portal of No. 3 adit was explored to an unknown extent by a shaft and two adits at an unknown date (pl. 1), but the underground geology and the amount of quicksilver mined were not learned.

A body of serpentine 450 by 850 feet crops out in the northeast corner of the map area (pl. 1) where the 1889-level shaft, after passing through some silica-carbonate rock, is said to have been sunk to a total depth of about 72 feet in serpentine. From the lower part of the shaft, a short drift is said to have been driven southwestward into silica-carbonate rock containing small amounts of cinnabar in veinlets of quartz and chalcedony, thereby suggesting that the prominent re-entrant angle in the margin of the serpentine outcrop may represent a southwestward plunging trough of the type that characterizes La Joya geology. There may be a genetic relationship with the main body of serpentine only 300 feet to the southwest.

Suggestions for Further Exploration. La Joya mine is one whose quicksilver is said to have come almost entirely from a string of ore bodies in one peculiarly shaped structural trough that was unusually effective in trapping quicksilver. The continuity of mineralization reported, and the amount of quicksilver obtained, point to additional exploration down the dip as one of the chief possibilities of the mine, despite the paucity of geologic information concerning the deposit, and the great uncertainty of finding additional ore at greater depth.

Additional structural troughs of similar type that may have trapped groups of ore bodies in the mine or its vicinity should be sought. The trough 500 feet southeast of the portal of No. 3 adit (pl. 1) has been explored to an unknown extent with unknown results. The lowest visible working in the area is an adit on the No. 3 level only 140 feet below the collar of the old shaft, and it is not known whether the workings have been deep enough to exhaust all possibilities of ore.

The apparent trough partly explored by the 1889-level shaft seems to dip southwestward toward the principal known ore deposit of the mine in the trough whose outcrop is only 650 feet distant. The history of the mine suggests that this 72-foot shaft may be less than half the depth necessary to afford an adequate test of the possible existence of ore deposits. The Whitton brothers are said to have sunk a shaft and other workings 165 feet below the outcrop in the main trough prior to 1873, apparently without finding the main part of the deposit; half or two-thirds of a century seems to have elapsed before the workings were deep enough and properly situated to encounter the richest part of the deposit. The trough of the 1889-level shaft seems less strategically situated than the other, however, and there may be no ore bodies in it.

It is believed that any additional deposits that might be found in favorable troughs or pockets containing silica-carbonate rock along the margins and blunt northwest end of the arm of serpentine that extends 1,000 feet northwest from the outcrop of the main ore-bearing trough, probably would be inferior in size and richness to any that might be found in the margin of the main serpentine body near the chief ore-bearing trough itself. However, the possibilities of finding ore in this part of the mine apparently have not been adequately explored.

Bella Oak Mine

The Bella Oak mine, known until about 1928 as the Bella Union mine, is 1½ miles northwest of Oakville in sections 20, 21, and 28, T. 7 N., R. 5 W., M. D., in the foothills at an altitude of 500 feet above sea level. The mine consists of the Oakville and Bella Union claims, each 1,000 by 3,000 feet, that were located in 1868, and merged in 1875 as the Bella Union mine. The recorded yield is 1,792 flasks of quicksilver (table 1). The mine has about 6,000 feet of underground workings known chiefly from old maps; only 1,400 feet were accessible in 1943. Development has been by adits and three inclined shafts; the workings are in three groups between which there are a few short adits that were unproductive.

History. The Oakville claim was located January 22, 1868, by W. W. Stillwagon, E. N. Boynton, S. Hutchinson, and O. P. Southwell,[23] who sold it about 1871 to the Oakville Quicksilver Mining Company of San Francisco for $30,000. A 10-ton Neate furnace began to reduce ore in February 1872 at the rate of 400 pounds of quicksilver per day,[24] and a 15-ton Neate furnace was completed in December 1872. In 1873, most of the ore consisted of cinnabar in ocherous clay averaging about 1 percent Hg, but the average of all ore treated to that date was 2¾ percent Hg. The scale of mining is shown by the fact that 16 white men and 30 Chinese were employed.[25] The ore was made into sun-dried adobes before being treated in the furnaces,[26] and the dump (pl. 3) consists principally of adobes. The Oakville claim was patented March 13, 1872,[27] and was sold November 11, 1872 to the Napa Quicksilver Mining Company of New York.[28]

The Bella Union claim adjoining the southeast end of the Oakville claim was located August 13, 1868 by Henry Rohlwing and others,[29] and was patented July 15, 1878.[30] The two claims became the Bella Union mine after the Bella Union Quicksilver Mining Company bought the

---

[23] Palmer, Lyman L., op. cit., p. 169.
[24] Mining and Scientific Press, March 2, 1872, p. 130.
Menafee, C. A., op. cit., p. 101.
[25] Menafee, C. A., op. cit., p. 101.
[26] Palmer, Lyman L., op. cit., p. 169.
[27] Napa County, California, Patents, vol. A, pp. 254-56.
United States, Patents, vol. 3, pp. 503-07.
[28] Napa County, California, Deeds, vol. Q, pp. 467-68.
[29] Napa County, California, Patents, vol. B, pp. 274-76.
Idem, Mining Deeds, vol. 1, p. 33.
[30] Napa County, California, Patents, vol. B, pp. 274-76.
United States, Patents, vol. 35, pp. 384-90.

Oakville claim May 10, 1875, and bought five-sixths interest in the Bella Union claim May 12, 1875 and the remainder August 10, 1876.[31] The mine was operated until the falling price of quicksilver and the low grade of ore stopped production on September 30, 1876,[32] and remained inactive until 1916, except for a little development work later in 1876[33] and in the winter of 1909-10.[34]

The Rutherford Mining Company operated the mine under lease intermittently from 1916 to 1920. The two old Neate furnaces built in 1872 were repaired and used for a short time in 1916, then a 12-pipe Johnson-McKay retort was built. An unsuccessful Lilliard furnace was built in 1917,[35] and a 4- by 56-foot rotary furnace was built in 1918.[36]

The mine became known as the Bella Oak about 1928, when it was leased by the Bella Oak Mining Company and a 3- by 40-foot rotary furnace was installed.[37] H. W. Gould and Company acquired the lease in 1930, and bought the mine from the Bella Union Quicksilver Mining Company about 1934. The mine was subleased in 1931 to J. Garcia. The rotary furnace was removed from the property about 1932 or 1933. Fred A. Bachich and T. C. Mellersh moved the 3- by 40-foot rotary furnace from La Jolla to the property in 1942, and operated the mine under lease until August 1943. H. W. Gould and Company sold the property in May 1944 to Martin Stelling Jr., of Rutherford,[38] who later sold the north half to J. J. Cohn of Beverly Hills, California.[39]

Geology. The ore bodies of the Bella Oak mine have been found in silica-carbonate rock formed from the lower part of a southwest-dipping tabular body of serpentine 30 to 50 feet thick that occupies the Bella Oak thrust fault. The fault strikes N. 45° W., and in the accessible workings the dip ranges from 10° to 35° S.W., with the exception of a small area in the vicinity of the foot of the Bachich 1943 shaft (pl. 3) where the dip flattens to zero, reverses to 12° NE., and rolls over again to 35° SW. in the lowest part of the workings. A similar roll in the fault is said to have been found in the lowest parts of the North workings. The hanging wall is conglomeratic sandstone of the Franciscan (?) group, and the footwall is black shale of the Knoxville (?) formation. The silica-carbonate rock is separated from the overlying serpentine by several feet of black gouge that contains a large amount of finely sheared serpentine, and from the underlying shale by a foot or two of black gouge. Between the main part of the lower gouge and the shale footwall in the southeast end of the Bachich 1943 workings lies a thin lenticular body of sheared serpentine.

The known ore bodies of the mine were found in three distinct groups that are marked roughly by the North, Central, and South groups of underground workings (pl. 3) separated by areas of little or no silica-carbonate rock. The three groups seem to mark the upper ends of plunging inverted troughs in the hanging wall that guided the quicksilver-depositing solutions upward along the fault.

---

[31] Napa County, California, Mining Deeds, vol. 1, pp. 35-36, 46.
[32] St. Helena Star, St. Helena, California, September 29, 1876.
[33] Idem, November 10, 1876.
[34] Bradley, W. W., op. cit., p. 80.
[35] Bradley, W. W., op. cit., p. 80.
[36] Ransome, F. L. Quicksilver in 1918: Mineral Resources U. S. 1918, pt. 1, p. 161, 1919.
Ransome, F. L. Quicksilver in 1919: Mineral Resources U. S. 1919, pt. 1, p. 169, 1921.
[37] Ransome and Kellogg, op. cit., p. 407.
[38] H. W. Gould and Company, personal communication.
[39] Martin Stelling Jr., personal communication.

The average thickness of the silica-carbonate rock in accessible workings of the three groups is about 7 feet, but the thickness differs greatly from place to place. The maximum thickness is in the inaccessible workings of the North (Oakville) group, where the rock in the gulch above the site of the old Neate furnaces cuts out the serpentine to come into contact with the overlying sandstone (pl. 3, section A-B), and the thickness may be as much as 50 feet. The maximum thickness in accessible parts of the Central and South groups of workings (pl. 3, sections C-D and E-F) is about 15 feet. The minimum thickness in most places between the main groups of workings is 2 or 3 feet, as in the 490 adit 375 feet southwest of the rotary furnace, but there are several places where no silica-carbonate rock crops out and the serpentine apparently is in contact with the underlying shale.

Cinnabar in the Bella Oak mine shows a marked tendency to occur in the lowest part of the silica-carbonate rock, as in the 490 adit and the winze of the 1943 workings, hence it is inferred that the quicksilver-bearing solutions in general followed the footwall of the fault where less gouge was encountered. Although cinnabar was concentrated in important amounts in some places in the lowest part of the rock, the best ore bodies were formed where cinnabar was deposited throughout the entire thickness of the rock. An example of such an ore body was the small vertical pipe said to have been found in the inaccessible workings near the foot of the South (490) shaft (pl. 3, section E-F).

In the central group of workings, the 1943 raise and winze 130 feet southeast of the foot of the Bachich 1943 inclined shaft (pl. 3, section C-D) exposed scattered cinnabar in silica-carbonate rock under a plunging inverted trough in the hanging-wall serpentine. The raise encountered a caved winze that had been sunk from the old stope farther up the dip, and it seems that the inverted trough was the distributary channel that guided the quicksilver-bearing solutions upward along the thrust fault into the large body of host rock of suitable degree of brecciation that lay under an area of markedly lessened dip in the hanging-wall serpentine.

Similar conditions probably were found in the north and south groups of workings although the only confirmatory evidence seen in the accessible workings was the abrupt roll in the hanging wall of the south stope down which the South (490) inclined shaft was sunk, and which terminated the stope so abruptly that the same horizon of the hanging wall that in most places formed the back of the shaft also formed the southeast side of the shaft. Cinnabar is said to have been found in some parts of the lowest workings in both the north and south groups.

The cinnabar seen in the 1943 winze and raise of the central group of workings, and that reported to have been found in parts of the lowest workings of the north and south groups of workings, simply mark the ''roots'' of ore bodies already mined out up the dip, and do not necessarily suggest any mineralization farther down the dip. These ''roots'' mark the trail by which the quicksilver-bearing solutions rose along the fault, and one can not refrain from wondering whether other ''pods'' of ore were formed farther back along that trail if exceptionally favorable conditions existed within reasonable distance of the surface. Great caution in following this reasoning is impelled by the fact that the deepest workings of the mine are said to be about 250 feet down the dip from outcrops, and many quicksilver mines apparently have been exhausted at this or lesser depth.

Suggestions for Further Exploration. Any further exploration of the Bella Oak mine obviously should continue down the thrust fault in the areas of the three main groups of workings that in a general way are believed to mark three major inverted troughs in the hanging wall. Although no silica-carbonate rock on the hanging-wall side of the fault is known, and nothing was seen in the short time available to suggest the presence of any other important structural channels or troughs favorable for prospecting, such possibilities of ore covered by slope wash or landslides should not be overlooked. The resistance of silica-carbonate rock outcrops in the area strongly suggests that the favorable areas already have been found.

The Bella Oak thrust fault may have been folded to some extent into anticlinal and synclinal folds at some time prior to the deposition of cinnabar, and the influence of such folding on the direction and distance to which underground workings might have to be driven to reach the silica-carbonate rock on the footwall of the fault might be costly. Many small rolls and some reversals to northeasterly dip have been found in the fault, and others may be expected at greater depth, but reconnaissance west and southwest of the mine suggested that the fault probably continues its general southwesterly dip at greater depth in the Bella Oak mine.

The authors saw no proof that the mine might not yield additional quicksilver in the future under exceptionally favorable economic circumstances, but there is great uncertainty.

Prospects

Cinnabar is said to have been found in silica-carbonate rock in the vicinity of La Joya and Bella Oak mines, and at several other places in silica-carbonate rock and Sonoma volcanics, but there is no record of production from any of these prospects.

MINES AND MINERAL RESOURCES OF TUOLUMNE COUNTY, CALIFORNIA

By Clarence A. Logan *

OUTLINE OF REPORT

Page
ABSTRACT 47
GEOGRAPHY 48
MINERAL RESOURCES 48
  Asbestos 48
  Chromite 49
  Copper 53
  Gold 54
    Summary 54
      The Mother Lode 55
      The east belt 55
      Pocket mines 56
    Description of gold quartz mines 56
    Gold placer mining 73
  Graphite 75
  Lead 75
  Limestone and marble 76
  Magnesite 80
  Molybdenum 81
  Slate 81
  Soapstone and talc 81
  Stone industry 82
  Tungsten 82
BIBLIOGRAPHY 83

Illustrations

Plate 4. Densmore mine 56-57
5. *A*, Harvard mine. *B*, Eagle Shawmut mill 56-57
6. *A*, Plant of Sonora Marble Aggregates Company. *B*, Old quarry of Columbia Marble Company 56-57
7. *A*, View northwest from Columbia, across Tuolumne-Calaveras County marble belt. *B*, Limestone bedrock exposed by early-day placer mining, Columbia 56-57
8. Map of western Tuolumne County showing locations of mines In pocket

ABSTRACT

Tuolumne County, one of the Mother Lode counties, extends from the eastern border of the Central Valley to the higher peaks of the Sierra Nevada, including San Francisco's Hetch Hetchy water system and part of Yosemite National Park. The Mother Lode highway gives road connection with Calaveras County on the north and Mariposa to the south. Two other state highways, one through Yosemite Park, extend from the west across the mountains to Nevada. Sierra Railroad gives a broad-gauge outlet for freight to main lines at Oakdale.

The county owes its early reputation as a gold-producer to the immensely rich placers of Columbia and Springfield, where $55,000,000 in gold was mined from shallow deposits in potholes and crevices of the limestone bedrock prior to 1899. The pocket mines of Sonora, Bald Mountain and vicinity have also been highly productive and exceptionally long-lived. No similar area anywhere has produced as much gold from comparable depths.

The Mother Lode traverses the county, but the development of its mines occurred later here than in other counties. The deepest mine on the lode here reached 3200 feet on the dip, and few have passed a depth of 2000 feet. The east belt contains hundreds of small gold mines and prospects. Veins are generally narrower, and ore shoots are shorter, more complex in mineral content, and richer in gold than those of the Mother Lode. Few of these mines have been active recently. Placer mining production in later years came principally from dragline dredges.

---

* District Mining Engineer, Sacramento district, California State Division of Mines. Manuscript submitted for publication July 15, 1948.

Marble and limestone products have been next to gold in value. The Columbia marble beds had a long history of production prior to 1941, and two plants are at present processing the stone from these deposits.

In common with the other counties along the western slope of the Sierra Nevada, Tuolumne contains deposits of chromite, copper, soapstone, scheelite, and slate. Magnesite has been produced and other metallic and nonmetallic minerals have been noted or have been shipped in small quantities.

The county participated in the gold mining boom of 1932-41, and in the difficulties that have beset that industry since. The present report is intended to bring up to date the record of mining there since our last report.[1] Three features are worth noting. These are the successful operation of the Eagle Shawmut mine on very low-grade gold ore during the last war; the substantial production in late years from pocket mines, some with histories going back to the fifties; and the tremendous limestone resources.

GEOGRAPHY

The part of Tuolumne County of principal interest to the miner is the westernmost one-third extending to the east line of Range 16 East, M. D. The three forks of Stanislaus River drain the northern part, and the southern half of the county includes the entire drainage basin of Tuolumne River. The easterly one-third of the county is within Yosemite National Park. State highways from the west enter from Knights Ferry and Melones, both on Stanislaus River, which forms the west boundary. These and connecting county roads give access to most of the mining districts. Lumbering is the principal industry. Sonora, the county seat, is at an elevation of about 1900 feet at the junction of two paved highways. Railway service to the Mother Lode mines, to Sonora and lumbering towns to the east is given by Sierra Railway of California which connects with the Southern Pacific Railroad at Oakdale, Stanislaus County. Little snow falls below the 2000-foot level. The dry season extends usually from May to November; most of the rainfall occurs during the first three or four months of the year. Summers are devoid of rain in the mining region, and in the southwestern section of the county, where the elevation is only a few hundred feet above sea-level, daytime temperatures may be high, but cause no distress because of the low humidity.

Timber, water, and electric power are available generally in the mining districts.

MINERAL RESOURCES

Gold, marble, and limestone have been the leading mineral products of Tuolumne County. Much of the limestone is dolomitic and some of it has been commercially classed as dolomite and so reported. Chromite, copper, clay, granite, magnesite, miscellaneous stone, soapstone, and slate have been produced, and in the sixties graphite was mined and shipped to England. Some by-product lead and silver from gold-quartz ores, and platinum found with placer gold, have also been reported. Chrysotile and amphibole asbestos, and diatomite occur within the county.

Asbestos

Prospects of both chrysotile and amphibole asbestos have been located in the county but so far have not been reported as productive.

Ashley prospect is 3½ miles south of Big Oak Flat on the Hetch Hetchy railroad back of the Segale Ranch. Lloyd Ashley, Jamestown, is the owner. This prospect of chrysotile was held for many years by H. Favot. The asbestos is short fiber, under 1 inch. At present Ashley is doing some experimental work with this asbestos.

---

[1] Logan, Clarence A., Sacramento field division—Tuolumne County: California Min. Bur. Rept. 24, pp. 3-53, 1928.

The large area of serpentine south and west of Chinese Camp has been prospected for chrysotile. Claims have also been located and held for years in the smaller body of serpentine west of Rawhide mine.

Rawhide asbestos claims Nos. 1, 2 and 3 are 1 mile west of Rawhide, adjoining the Williamson land and probably in SE¼ sec. 5, T. 1 N., R. 14 E. They were located in 1940-41 by C. F. Cowan. They cover a prospect of short-fiber chrysotile asbestos, some samples of which indicate commercial possibilities.

Gail W. Holmes, Route 1, Sonora, did some work in 1943-44 on a prospect of amphibole asbestos. The exact location was not reported, but such material has been noted by Eakle[1a] as occurring near Chinese Camp and Montezuma, and clusters of white fibrous tremolite may be seen here and there in the great marble deposits in the county.

Chromite

The existence of chromite ore near the old Crimea House, 4 miles southwest of Chinese Camp, was noted in 1867.[2] This is on the southwest side of the large serpentine area extending from about 7 miles southeast of Chinese Camp in a northwesterly direction. Other smaller bodies of serpentine are exposed irregularly along the course of the Mother Lode. In the Second Report of the State Mineralogist, 1883-84, page 138, mention is made of the Engel mine at York Tent near Chinese Camp, and the same volume alludes to the opposition of chromite producers to furnishing production figures. No accurate figures of output in early days from any of the mines are available.

The most important producer has been the McCormick mine in sec. 2, T. 1 S., R. 13 E., which yielded several thousand tons of high-grade chromite. According to Peter Mackey, the ranch in secs. 21, 28, T. 1 N., R. 14 E., then called the Mackey Ranch, produced 500 tons of 40 percent chromite ore prior to 1914. This was shipped to San Francisco. On the Marianno Ranch in secs. 4, 5, 8 and 9, T. 1 S., R. 14 E., five carloads of chromite ore that had been gathered from small loose masses on and near the surface was shipped to San Francisco prior to 1914.

During World War I, these and numerous other properties were actively prospected and except for the McCormick mine, most of the ore of shipping grade within easy reach of the surface was mined and sold. According to statistics published by the State Mining Bureau,[3] 7586 tons of chromite ore, which sold for a total of $229,891 was mined and shipped from Tuolumne County from 1915 to 1918 inclusive. Some production was made in 1919, from 1931 to 1934 inclusive, and in 1939. Nearly all of this came from the McCormick mine which is credited with producing over 1300 tons during 1931-34. The ore from this mine was high grade and during the 1930's went mostly to Columbia Steel Company. In spite of its high chromite content it brought only $15 a ton loaded on the cars.

[1a] Eakle, Arthur S., Minerals of California: California Min. Bur. Bull. 91, p. 167, 1923.

[2] Browne, J. Ross. Mineral resources of the states and territories west of the Rocky Mountains (for 1867) p. 224, 1868.

[3] Bradley, Walter W. Mineral production (of California) for 1915, 1916, 1917, 1918: California Min. Bur. Bulls. 71, 74, 83, 86.

MINERAL PRODUCTION OF

Year	Gold, value	Silver, value	Lime		Limestone	
			Barrels	Value	Tons	Value
1880	$461,861	$1,071	----------	----------	----------	----------
1881	500,000	1,000	----------	----------	----------	----------
1882	400,000		----------	----------	----------	----------
1883	320,000	----------	----------	----------	----------	----------
1884	310,000	----------	----------	----------	----------	----------
1885	320,903	1,473	----------	----------	----------	----------
1886	432,438	1,551	----------	----------	----------	----------
1887	504,662	3,166	----------	----------	----------	----------
1888	475,000	3,500	----------	----------	----------	----------
1889	446,300	543	----------	----------	----------	----------
1890	1,500,629	13,062	----------	----------	----------	----------
1891	1,384,950	139	----------	----------	----------	----------
1892	1,092,549	911	----------	----------	----------	----------
1893	354,734	1,329	----------	----------	----------	----------
1894	547,448	1,072	----------	----------	----------	----------
1895	666,754	313	----------	----------	----------	----------
1896	1,070,141	328	----------	----------	----------	----------
1897	1,809,572	1,696	----------	----------	----------	----------
1898	1,734,953	15,582	----------	----------	----------	----------
1899	1,635,769	15,111	----------	----------	----------	----------
1900	1,596,891	62,367	----------	----------	----------	----------
1901	1,670,368	39,787	----------	----------	----------	----------
1902	1,791,829	6,580	----------	----------	----------	----------
1903	1,732,572	13,989	1,600	$1,600	----------	----------
1904	1,563,907	12,963	----------	----------	----------	----------
1905	1,291,726	21,348	500	1,000	----------	----------
1906	1,039,675	8,476	500	1,000	----------	----------
1907	806,875	6,453	110,000	125,000	----------	----------
1908	798,752	11,732	60,000	69,500	1,233	$6,500
1909	925,703	4,384	60,000	60,000	15,057	28,942
1910	615,626	5,754	78,300	78,300	3,600	10,400
1911	1,093,484	13,243	75,000	70,000	4,319	13,609
1912	1,113,291	25,146	117,450	121,250	11,554	20,099
1913	974,409	24,381	75,000	85,000	12,446	20,676
1914	940,793	12,017	63 331	38,000	16,707	21,907
1915	1,058,103	13,480	(7)	----------	8,859	11,349
1916	868,237	17,039	(7)	----------	3,137	5,132
1917	321,085	7,808	(7)	----------	3,287	6,481
1918	274,328	21,425	(7)	----------	3,064	5,600
1919	471,021	11,076	(7)	----------	(2)	----------
1920	254,569	6,007	(7)	----------	7,494	15,288
1921	96,026	2,505	(7)	----------	3,650	9,475
1922	222,366	2,976	----------	----------	----------	----------
1923	261,936	2,801	----------	----------	3,140	7,680
1924	255,994	1,106	----------	----------	8,515	19,983
1925	155,592	614	----------	----------	----------	[4]268,000
1926	119,873	1,119	----------	----------	----------	----------
1927	40,209	302	----------	----------	(7)	----------
1928	36,807	185	(7)	----------	(7)	----------
1929	70,957	2,735	(7)	----------	(7)	----------
1930	67,691	300	(7)	----------	(7)	----------
1931	77,902	180	(7)	----------	(7)	----------
1932	93,939	214	(7)	----------	(7)	----------
1933	107,736	280	(7)	----------	(7)	----------
1934	269,256	1,147	(7)	----------	(7)	----------
1935	286,062	1,979	(7)	----------	(7)	----------
1936	476,105	3,028	(7)	----------	(7)	----------

TUOLUMNE COUNTY, 1880-1946

Marble		Copper		Miscellaneous stone*, value	Miscellaneous and unapportioned		
Cubic feet	Value	Pounds	Value		Amount	Value	Substance
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	800 M	$2,288	Brick.
--------	--------	--------	--------	--------	--------	--------	
--------	--------	--------	--------	--------	--------	1,301	Unapportioned, 1900-09.
--------	--------	--------	--------	--------	400 lbs.	16	Lead.
7,000	$14,000	155,826	$17,920	--------	--------	--------	
11,550	28,875	--------	--------	--------	10,367 cu. ft.	14,020	Granite.
11,500	28,750	--------	--------	--------	9,700 cu. ft.	9,700	Granite.
11,000	66,000	--------	--------	--------	9,700 cu. ft.	9,700	Granite.
23,000	46,000	--------	--------	--------	9,700 cu. ft. 197 tons	9,700 1,379	Granite. Chromite.
22,030	60,120	--------	--------	--------	--------	--------	
18,503	47,165	140,000	--------	--------	--------	--------	
27,600	107,400	9,086	1,154	--------	30 tons	180	Chromite.
17,360	47,400	--------	--------	--------	2,052 lbs.	111	Lead.
18,966	50,398	--------	--------	--------	--------	--------	
27,720	73,920	--------	--------	--------	--------	--------	
37,312	93,726	893	138	--------	893 lbs.	53	Lead.
21,830	38,202	45	6	--------	89 lbs.	3	Lead.
(7)	--------	27,667	4,842	1,900	352 tons 1,779 lbs. --------	2,352 84 79,328	Chromite. Lead. Dolomite, lime, marble.
(7)	--------	1,797	442	1,500	285 tons 873 lbs. --------	4,556 60 107,296	Chromite. Lead. Dolomite, lime, magnesite, marble.
(7)	--------	32,840	8,960	3,800	2,680 tons 997 lbs. --------	54,290 86 108,758	Chromite. Lead. Dolomite, lime, magnesite, marble.
(7)	--------	35,127	8,676	1,700	4,269 tons --------	168,693 121,806	Chromite. Lime, manganese, marble.
(7)	--------	(7)	--------	2,700	-------- --------	110,746 78,950	Lime and limestone. Chromite, copper, granite, marble.
(7)	--------	--------	--------	28,696	--------	209,354	Dolomite, lime, marble, platinum.
(7)	--------	--------	--------	229,185	--------	217,292	Dolomite, granite, lime, marble.
--------	--------	--------	--------	246,460	--------	293,136	Other minerals.[1]
--------	--------	--------	--------	9,800	--------	388,145	Other minerals.[2]
--------	--------	--------	--------	12,500	--------	339,573	Other minerals.[3]
--------	--------	--------	--------	29,751	--------	113,305	Other minerals.[5]
--------	--------	2,332	326	56,097	--------	438,583	Other minerals.[6]
(7)	--------	--------	--------	31,416	--------	360,489	Limestone, marble, slate.
(7)	--------	--------	--------	9,090	--------	330,196	Dolomite, lime, limestone, marble, pumice, slate.
(7)	--------	82,383	14,499	11,415	--------	271,914	Dolomite, lead, lime, limestone, marble, slate.
(7)	--------	4,566	593	(7)	317 lbs. --------	16 249,722	Lead. Lime, limestone, marble, slate, miscellaneous stone.
(7)	--------	(7)	--------	100,785	--------	198,290	Chromite, copper, lime, limestone, marble, slate, soapstone.
(7)	--------	--------	--------	87,814	--------	118,491	Chromite, lime, limestone, marble, slate, soapstone.
(7)	--------	--------	--------	11,020	--------	145,943	Chromite, lime, limestone, marble, slate.
(7)	--------	--------	--------	5,578	--------	147,607	Chromite, lime, limestone, marble, slate.
(7)	--------	(7)	--------	39,350	--------	147,219	Copper, lead, lime, limestone, marble, slate.
(7)	--------	10,082	927	71,968	--------	171,441	Lead, lime, limestone, marble, slate.

MINERAL PRODUCTION OF

Year	Gold, value	Silver, value	Lime		Limestone	
			Barrels	Value	Tons	Value
1937	$690,585	$6,155	(7)	----------	(7)	----------
1938	854,490	4,544	(7)	----------	(7)	----------
1939	422,240	2,059	(7)	----------	(7)	----------
1940	767,620	3,496	(7)	----------	19,904	$46,122
1941	804,895	4,107	(7)	----------	(7)	----------
1942	443,555	2,575	----------	----------	(7)	----------
1943	363,965	2,560	----------	----------	(7)	----------
1944	202,860	2,028	----------	----------	----------	----------
1945	164,360	1,997	----------	----------	----------	----------
1946	58,170	885	----------	----------	----------	----------
Totals	$44,583,098	$459,179	[7]641,681	$650,650	[7]125,966	$527,243

Grand total value, $56,066,123

* Includes crushed rock, macadam, rubble, sand, gravel.
[1] Includes mineral paint and sandstone.
[2] Includes granite, lime, magnesite, marble.
[3] Includes clay, dolomite, granite, lime, marble.
[4] Includes lime.
[5] Includes dolomite, granite, marble.
[6] Includes granite, lead, lime, limestone, magnesite, marble, silica.
[7] See under "Miscellaneous and Unapportioned."

When chromite prospecting and mining was resumed in 1941 under the stimulus of World War II, it was found that most of the easily accessible shipping ore had been previously mined. Specifications for ore were also much stricter than they had been during the previous war. No new deposits of importance were discovered. The result was that little production (about 600 tons) was made from 1941-44 inclusive. Some attention was given to prospecting and developing milling ore, and a small tonnage of this was found, but little milling was done.

McCormick chrome mine, in sec. 2, T. 1 S., R. 13 E., is $1\frac{1}{2}$ miles from the Sierra Railroad. It has been the principal producer of chromite in the county. The old Terry & Sell workings are on the same land 800 to 1000 feet northwest of the McCormick shaft. Prior to 1940, Robert McCormick, the owner, stated that the McCormick workings had produced about 3500 tons of chromite and the Terry & Sell about 1500 tons. The ore carried 45 to 48 percent Cr_2O_3, 10.8 to 10.9 percent Fe, and $3\frac{1}{2}$ to 5 percent SiO_2. During World War II, the McCormick shaft was deepened from 178 feet to 216 feet and 254 tons of ore was produced. From October 1943 to February 1944, the U. S. Bureau of Mines explored the land.[4] A total of 18,500 feet of diamond drilling, 680 feet of jackhammer drill holes and 200 feet of drifting and raising was done. As a result of this work they estimated that from 215 to 500 tons of 47 percent chromite remained in the mine.

---

[4] Julihn, C. E., and Moon, Lowell B., Summary of Bureau of Mines exploration projects on deposits of raw material resources for steel production: U. S. Bur. Mines Rept. Inv. 3801, 33 pp., 1945.

TUOLUMNE COUNTY, 1880-1946—Continued

Marble		Copper		Miscellaneous stone*, value	Miscellaneous and unapportioned		
Cubic feet	Value	Pounds	Value		Amount	Value	Substance
(7)	----------	6,157	$745	$130,747	----------	$183,948	Lead, lime, limestone, marble, slate.
----------	----------	2,899	285	84,568	----------	186,377	Granite, lead, lime, limestone, slate.
(7)	----------	9,860	1,025	25,277	----------	219,243	Chromite, dolomite, lead, granite, lime, limestone, marble, platinum, slate.
(7)	----------	4,649	525	60,620	----------	154,194	Lead, lime, marble, slate, soapstone.
(7)	----------	9,177	1,083	132,318	----------	200,502	Chromite, lead, dolomite, lime, limestone, magnesite, marble, slate.
----------	----------	4,555	551	110,390	----------	289,509	Chromite, dolomite, limestone, tungsten ore.
----------	----------	4,933	641	67,067	----------	349,275	Chromite, dolomite, limestone.
----------	----------	13,993	1,889	----------	----------	258,957	Chromite, dolomite, limestone, soapstone, stone (miscellaneous).
----------	----------	----------	----------	28,275	----------	239,994	Dolomite, limestone, soapstone, clay (pottery).
----------	----------	----------	----------	78,471	----------	262,441	Copper, dolomite, limestone.
[7]255,371	$699,756	[7]418,867	$65,232	$1,710,303	----------	$7,370,662	

Detailed descriptions of many small deposits are given in a recent report written as a result of one of the strategic minerals investigations made by the U. S. Geological Survey during World War II.[5]

Copper

The most westerly of the mineral zones in Tuolumne County is the foothill copper belt, of which one branch enters at Byrne's Ferry west of Chinese Camp and crosses the extreme southwestern part of the county. It contains two mines, the Oak Hill and Salambo, both former producers. Another group of copper prospects farther east near the Mother Lode has produced smaller tonnages of ore from time to time. Some copper prospects have also been reported from the region east of the Mother Lode. In some cases, the gold ores of the Mother Lode carry a small amount of copper which has been recovered in the concentrate. The only record of this available for publication is the production from the Eagle Shawmut mine for the last few years of operation. Only those properties that are known to have made some production are mentioned below. Older reports, including Bulletin 50 of the State Mining Bureau, may be consulted for reference to others.

Greenstone mine (see Mann).

Mackey Ranch (agricultural patent) is in secs. 21, 28, T. 1 N., R. 14 E., 2½ miles west of south of Jamestown. Although it was prospected in a limited way over a long period, the only recorded production was in 1915 when 15 tons of ore yielded 10 percent copper, $7 gold, and $1 silver per ton. The ore was taken from a vein 4 to 12 inches wide in a gossan-capped, lens-shaped ore body from 10 to 30 feet wide striking northwest and dipping northeast with serpentine footwall and schist hanging wall. The deepest work was a shaft about 130 feet deep at time of last visit. The ore contained copper carbonates, chalcopyrite, and pyrite.

Mann copper mine contains three claims, of which the Greenstone, in N½ sec. 28, T. 1 N., R. 14 E., has been productive. It adjoins the Mackey copper on the south, and is geologically similar. In 1912, this mine produced about 500 tons of low-grade gold ore. In 1917, over 200 tons of ore carrying copper carbonates and sulfides yielded about 3 percent copper.

---

[5] Cater, Fred W. Jr., Chromite deposits of Tuolumne and Mariposa Counties, California: California Div. Mines Bull. 134, pt. 3, pp. 1-32, 1948.

Oak Hill mine is in sec. 30, T. 2 S., R. 14 E., on an agricultural patent 4 miles southeast of Cooperstown, a station on the Sierra Railroad of California. It has been worked at intervals since 1870.

It was first operated as a gold mine and it is claimed that the gold production from the gossan ore was large, but definite details are not available. Sulfide ore containing chalcocite and pyrite was found at a depth of about 100 feet, and chalcopyrite, as well as bornite, some arsenopyrite, and considerable zincblende, occurred a little deeper.

The country rock is augite porphyrite and the ore is mineralized schist in a steeply dipping zone about 150 feet wide between two large quartz veins. The remaining gossan cap carries some gold, silver, and copper.

The main shaft has been sunk 580 feet and a total of about 2000 feet of drifts have been run from it, all on the south side of shaft. Ore with an average width of 2 feet has been stoped from the 350-foot level nearly to the surface on the south side. A drift was run 95 feet on the 450-foot level and is claimed to be in ore. On the 550-foot level on account of the pitch of the ore body, the 50-foot drift had not yet entered ore. Another shaft was sunk 114 feet at a point 800 feet south of the main shaft. A drift was run 200 feet from this.

The last production was in 1929-30, when several hundred tons of ore yielded nearly 5 percent copper, 5 ounces silver, and several dollars gold per ton.

Gold

Summary

The year 1928, when the last Division of Mines report on mining in Tuolumne County was published, was one of small gold production. Only four mines produced over 100 ounces of gold—the Hudson pocket mine, the Mountain Lily, Mother Lode Extension or 55 mine, and Mark Twain Mining Company, which operated the Chilano, Atlas, and Soldiers Gulch claims on Jackass Hill. In 1929, at the height of the period of high prices, and at a time unfavorable for gold mining because of high operating costs, the only important producer in the county was the Sugarman-Nigger pocket mine which yielded over $36,000. The Lazar pocket mine was the only other mine of 27 of this type in operation which produced over 100 ounces of gold. The Oak Hill mine, with a total production of about $17,000 of gold, silver, and copper, was in second place as a metal producer.

There was little improvement in gold mining for several years, during which production came almost entirely from many small pocket mines, and a few other small east belt lode mines. The report on the Mother Lode gold belt of California [6] brought the history of that lode in the county up to the time when some of the Mother Lode mines were resuming production. Gold output gradually increased to $805,000 in 1941, but was cut to a little over half that amount in 1942 because of the war. Due to increasing costs for labor, machinery, timber, and other supplies used in mining, there has been further recession. The working of low-grade ores known to remain in some of the Mother Lode mines, notably the Harvard and Eagle Shawmut, awaits more favorable conditions. Meanwhile, the pocket mines and some small lode mines of the east belt which have better than average ore will keep the county in the list of gold producers.

---

[6] Logan, Clarence A., Mother Lode gold belt of California: California Div. Mines Bull. 108, pp. 153-179, 1934.

The following notes are intended to cover mining activities since 1928, as well as to describe properties not adequately covered in the Division's earlier reports.

The Mother Lode. The Mother Lode outcrops are not continuous through Tuolumne County. Most of the productive mines have been in the section between Robinson's Ferry (Melones) on the north and Sullivan Creek, a distance of 9 miles. A second section of the lode, about 6 miles long, extends from 1 mile south of Sullivan Creek to Stephens Bar bridge, where Tuolumne River crosses the lode. In this section, the principal producer has been the Eagle Shawmut mine. In the remaining 8 miles to the Mariposa County line, developments have been scattered and shallow.

In those places on the lode in this county where the more productive mines occur, the lode is characterized by large masses of white quartz and ankerite, locally called the ''bull quartz'' vein. These may be seen at Whiskey Hill, Quartz Mountain, Golden Rule Hill, Shawmut, and McAlpine. In these regions the lode is a broad series of veins in which ore generally occurs either in the footwall or hanging wall veins. The ankerite of the ''bull quartz'' vein is generally seamed with a network of quartz veinlets and contains enough iron to resemble gossan when weathered. Although the ankerite usually carries a little gold, the amount is seldom sufficient to repay mining and milling. An ore shoot was found in the ankerite at the Rawhide mine in 1893, however, and dolomite sulfide ore of different origin occurs in the Shawmut mine.

The mines here are in amphibolite schist or along the contact of that rock, or serpentine or other meta-intrusives, with the Calaveras (Carboniferous) rocks. The Mariposa slate (Jurassic) lies west of the principal mines in this county and although it extends the entire length of the county, few mines have been found in it; but it forms one wall at the Shawmut mine.

The ores are not ''free-milling'', as that term is generally understood, as a large part of the gold is associated with sulfides, mostly pyrite. The percentage of sulfides in the ore is two to four times as great as in the ores found in the Mariposa slate in other counties on the Mother Lode. Most of the ore is medium or comparatively low grade, and the concentrate, being rather copious in quantity and relatively low in gold content, could be most economically treated on the property to save freight, treatment charges, and deductions made by smelters. The recent operations at the Eagle Shawmut mine, show what can be done with such ore. Another large enterprise, which has been held in abeyance awaiting a return of reasonable conditions, is the operation of the Harvard mine near Jamestown.

The East Belt. In the five counties traversed by the Mother Lode, the term ''east belt'' has come into general use and acceptance to designate the gold mining area east of the Mother Lode. In Tuolumne County, the east belt extends about 20 miles east of the Mother Lode, to an elevation of 4000 to 4500 feet. The rocks mapped as the Carboniferous, consisting of a complex of hard clay-slate, limestone, mica schist, and various meta-intrusives now generally altered to schist, were invaded and uplifted in Cretaceous time by the Sierra Nevada batholith, and tilted to the west in Tertiary time or later. The uplifting and tilting rejuvenated the streams and accelerated erosion, so that much of the rock once covering the granite has been swept away, exposing numerous higher parts of the batholith. Most of the more productive east belt mines have been found in the border zones of the granitic rock or nearby in the older slate and schist.

The veins in the clay slate are generally "ribbon rock" of quartz with thin slate layers, conform in dip (steeply northeast) and strike (northwest) with the schistosity of the slate, and are free-milling, with pyrite as the principal sulfide. The Providence mine was an example. In the mica schist, the veins following the schistosity may be lenticular. In the granitic rocks, the veins carry considerable pyrite, galena, pyrrhotite, marcasite and some zincblende and chalcopyrite in small ore bodies, some of which are rich enough to make shipping ore; but there may also be ore shoots of lower grade in wide quartz veins which contain sufficient calcite to cause the quartz to break and crumble on exposure. Such ore has been worked in stamp mills and the tailing has been cyanided. In many of the east belt mines the deposition of ore appears to have been localized by dikes intersecting the veins, or where a dike or spur of the granite makes contact with the vein.

Pocket Mines. Pocket mining has been successfully followed in many widely separated parts of Tuolumne County, from the southwestern corner to the mountains, through a vertical range of 3000 to 4000 feet, and in most of the formations. The largest pocket producer in the state is the Bonanza mine at Sonora; many other large pockets have been mined near there. Bald Mountain, Jackass Hill, and the region around Columbia have been prolific producers of pockets. Many of the Mother Lode mines were first worked for pockets, and the mines in the vicinity of Big Oak Flat have been essentially pocket producers. The same may be said of many small mines in the rest of the east belt. The quartz removed in the search for pockets was usually saved and from time to time was crushed in small stamp mills, so that these mines have been listed as lode gold producers at irregular intervals.

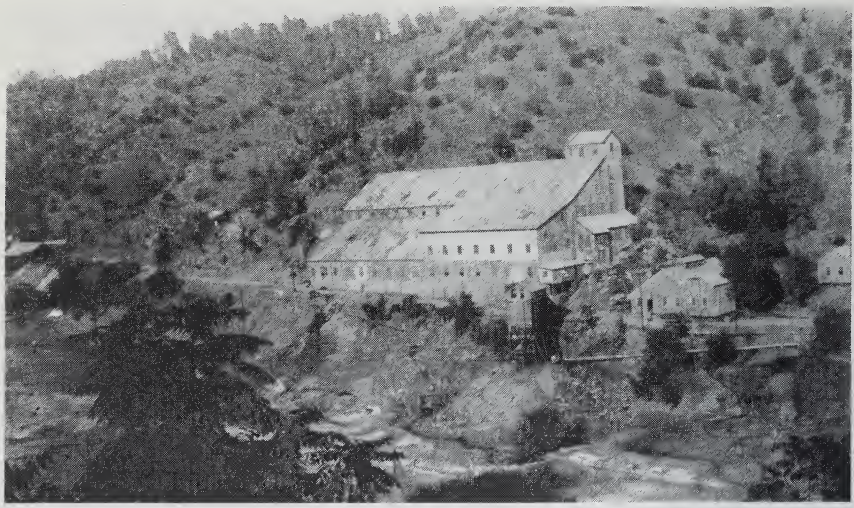
It is nearly impossible to publish accurate production figures for most of the pocket mines. In the first place, there is usually a tendency on the part of the public and local papers to overestimate the value of a pocket discovery. On the other hand, much of the gold so found, especially the larger or more attractive pieces, has not reached the mint promptly, but has passed into the hands of private collectors. Such pieces generally command up to double the mint price, as specimens. The erosion of the upper parts of pocket deposits supplied the coarse gold which enriched the placer deposits of Columbia, Shaws Flat, and Sonora. No other part of the state equals Tuolumne County in the number or productivity of its pocket mines.

Description of Gold Quartz Mines

Alabama mine is in sec. 9, T. 1 N., R. 14 E., and is assessed to Charles E. Shafer, Jamestown. It was partially prospected in 1922 by Tonopah Mining Company by means of an adit run from the 600-foot level of the Crystalline shaft, to a point below the old Alabama shaft, which is 300

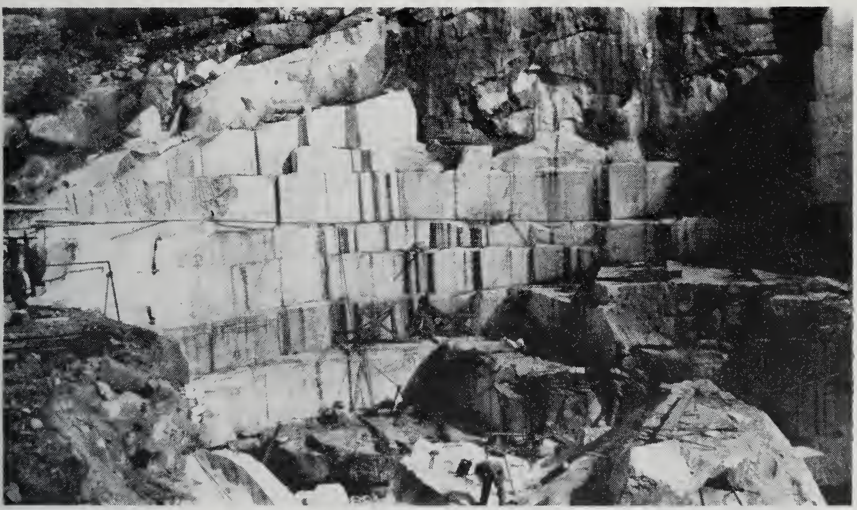
DENSMORE MINE
View southeast toward mill and surface

A, HARVARD MINE
On Whiskey Hill near Jamestown, as seen from the south



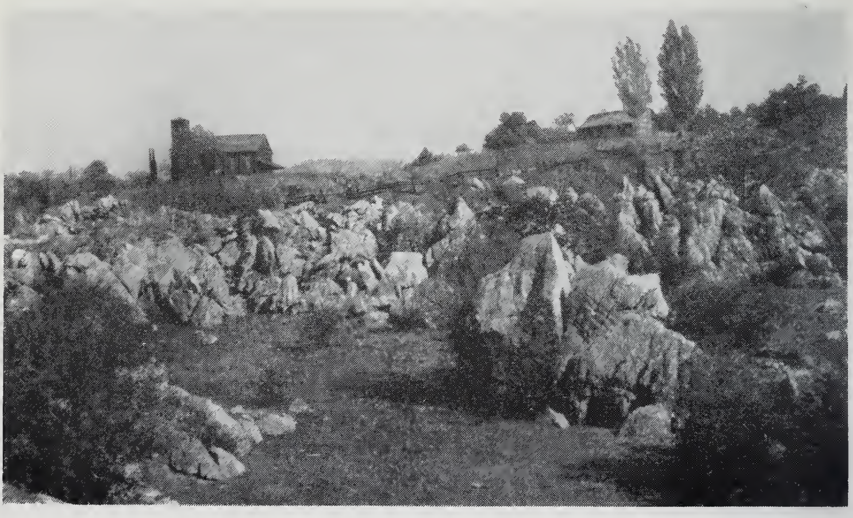
B, EAGLE SHAWMUT MINE
Looking northeast across Woods Creek toward mill building

A, SONORA MARBLE AGGREGATES COMPANY
View northeast toward plant near Columbia



B, COLUMBIA MARBLE COMPANY
Old quarry pit, which has been idle for several years

A, TUOLUMNE-CALAVERAS COUNTIES MARBLE DEPOSIT
View northwest from Columbia. The canyon of Stanislaus River extends across the region in the middle distance



B, LIMESTONE BEDROCK
Exposed by early placer mining near Columbia

feet deep. The early-day production came from open cut and glory hole workings.[7] The Alabama is on the north end of Whiskey Hill and is now held jointly with the Crystalline. In 1922, when the work mentioned was done, sufficient time was not allowed to permit crosscutting the Mother Lode on the 600-foot level, so that in spite of this work having extended for 820 feet on the strike under the Alabama claim, little was learned about the lode, which is 60 feet wide on this claim.

In 1947, C. E. Wood of Hawood Corporation unwatered the Alabama shaft, drifted 80 feet and crosscut 47 feet on the 300-foot level. He reports finding a good prospect in a vein 6 feet wide which was crossed. This work was presumably stopped in favor of a resumption at the Gross and Street mines when electric power became available again.

Alameda mine, 3 miles northwest of Jamestown on the Mother Lode, is just north of where the serpentine and Calaveras rocks turn west. A narrow dike, later altered to amphibolite schist, was intruded into the contact zone between the serpentine footwall and the Calaveras rocks of the hanging wall. The lode courses northwest along this dike.

The claim was worked superficially in early days over a length of 1000 feet and is said to have paid well. In 1889 it was prospected by Hayward and Hobart and $1067 was produced. From 1894 to 1899 it was more extensively opened by Colonel Neville who was working the App mine at the time. He sank the north shaft to 920 feet and drifted and ran crosscuts on several levels to prospect the footwall vein which is composed of stringers and small lenses of quartz in the ankeritic and talcose material which was over 135 feet wide on the 500-foot level, and had a maximum width of 160 feet. Six levels were run and about 3000 feet of underground work reported on this vein. A 20-stamp mill was put up in 1898, but there appears to be no published record of production for that period, and the mill had been removed by 1903. On the south end of the claim the east (hanging wall) vein, 18 inches to 2 feet thick, was prospected to an inclined depth of 400 feet by a shaft, and also by adits, the longest reported to be 800 feet long. This vein was stoped to a depth of only 70 feet.

No further work was reported until 1938 when Hemming Brothers leased the claim. They installed two batteries of three stamps each, a ball mill, a classifier, amalgamation plates and concentrator, and milled some ore during 1938 and 1939 from the upper part of the old workings, most of which were caved. In 1938, 456 tons was reported milled, with a recovery of 90 percent, yielding $9.65 a ton.

Albion Consolidated Group (formerly the Great Eastern) of five claims in sec. 2, T. 1 S., R. 14 E., lies along the contact of Mariposa slate on the west and amphibolite schist on the east, about 1½ miles northeast of Chinese Camp. Although the claims were worked superficially in early days, no definite record remains of the production. One old drift was reported to contain ore that showed good assays.

In 1932, a group of San Diego people including O. T. & H. L. Dennhardt, D. & C. Thie, W. Trepte, and Peter Compton installed a Forrester-Rexman rod mill and Gibson impact amalgamator and milled some ore taken out of the 50-foot level of a shaft they were sinking. The vein was up to 4 feet wide in the shaft, which was sunk to about 100 feet.

---

[7] Logan, Clarence A., The Mother Lode gold belt of California: California Div. Mines Bull. 108, pp. 155-156, 1928.

Amario (see Junction).

Anderson & Amberg claim is near the Spring Gulch mine in sec. 21, T. 1 N., R. 16 E. Chester Anderson and Knute Amberg, Tuolumne, produced some high-grade ore from a vein on which they sank a shaft to a depth of about 100 feet in 1935. A prospecting mill was used to recover free gold only.

App, Dutch, Heslep and *Hitchcock* mines on the Mother Lode at Quartz Mountain, 2 miles south of Jamestown, have been fully described separately in past publications of the Division of Mines, up to 1934.[8] Thereafter, late in 1934, work was started under contract for Quartz Hill Mining Company, a California corporation. The Heslep shaft was reopened to the 100-foot level and a drift on that level was extended 200 feet south and 80 feet north on a vein 12 to 18 feet wide. Late in 1935 a plant containing a Straub ribcone 5- by 4-foot ball mill, a gold trap, a Dorr classifier, two concentrators, and four flotation cells, was put in operation. In the last four months of 1935, about 5000 tons of ore was milled from the vein mentioned, partly from the 100-foot level and partly from an open cut. In April 1936 milling was suspended and the reopening of the App shaft was started. It was re-timbered to the 280-foot (second) level and a crosscut was run 200 feet east to the Heslep vein, on which a drift was run 380 feet and stoping was started. Gold Diggers Syndicate, Inc., incorporated in Delaware in 1936, took over operation that year. About 10,000 tons of low-grade ore was milled in 1936. In 1937, a total of 14,323 tons was mined and milled; one shrinkage stope worked from the second level was 80 feet long by 80 feet high and up to 40 feet wide. After the App shaft was reopened and repaired to the third level, the Heslep vein was also worked from there. In 1938 the output was 16,445 tons which yielded 608 tons of concentrate from which 2327 ounces of gold and 1495 ounces of silver was recovered. The amount of free gold saved is not known, but previously about 80 percent of gold was recovered in concentrate. The concentrate was shipped to Selby smelter. A royalty of 10 percent was paid to the owners, Sonora Abstract & Title Company. The lease extended only to the 800-foot level, and neither this company nor its successor, Allied Mines, Inc. which took over the mine May 1, 1939, is known to have worked below the third level. Milling was resumed October 1, 1939 and continued through 1940 with a production of about 16,500 tons of ore. Of this, 6609 tons milled in 1939 gave 161 ounces of gold and 40 ounces of silver in bullion, and 232 tons of concentrate which yielded 563 ounces of gold and 342 ounces of silver.

Atlas (Waters) mine near the center of sec. 30, T. 2 N., R. 14 E., contains 26.98 acres. It is assessed to Martha A. Stoner, R.F.D. 1, Sonora.

The vein is a stringer lead of quartz and calcite in altered amphibolite schist. It averages about 10 feet in width, but in places reaches 30 feet. Although the mine had a mill and ''sulphurets'' plant in 1880, and other mills since, its principal production has been from pockets. In explanation of the persistent efforts of miners to develop milling ore bodies here, it must be remembered that the miners had the idea that in depth the stringers would unite and make a vein of workable width. So far, this hope has not been realized.

The Atlas was worked on the surface for 1000 feet or more in search of pockets. Several later operators worked for short periods to sink two shafts. The main shaft reached an inclined depth of 450 feet on 46°

---

[8] Logan, C. A., op. cit., 1934, pp. 153-179.

incline and a west shaft was sunk 124 feet. A 10-stamp mill was erected in 1913. Ore was stoped and milled at an operating cost of $2.80 a ton; although it was reported worth an average of $5 a ton, the actual yield during this time (1913-16 inclusive) was usually higher, indicating that pockets were being milled with lower grade material.

No further production was reported until 1928 when Mark Twain Mining Company stated over $9000 of "high grade" was taken from a group of claims including the Chilano, Atlas, and Soldiers Gulch. Local news items of that year announced discovery of two pockets, one of about $3000 and another of nearly $8000 by Henry Bernard, on the Atlas claim, the two being worth $10,705. Bernard also worked the claim for pockets for several years afterward, and made very substantial production. In 1938, George Engelke and Zeke Goodwin took a pocket worth several hundred dollars from within a few feet of the surface.

Bacigalupi mine (see Baker Ranch, Sunny South).

Baker Ranch near Tuolumne was prospected by Burm-Ball Mining Company in 1934 and 1935. A double-compartment shaft was sunk 550 feet; about 400 feet of crosscuts and 800 feet or more of drifts were run on a vein claimed to be the "Columbus-Dead Horse vein" as the property lies between these two mines. The amount of production is not known. The vein was reported 20 feet wide.

The same company also leased mineral rights on the Gibbs Ranch near Confidence, and did some work on the Sunny South claim, a former small producer, in the SW¼ sec. 33, T. 2 N., R. 16 E., but so far as known made no production from any of these operations.

Bicknell mine is 1 mile southeast of Big Oak Flat in secs. 29, 32, T. 1 S., R. 16 E. Norman Smith et al., 527 Maud Avenue, San Leandro are the owners.

This mine was worked in early days for pockets. A wide vein of quartz strikes nearly east in the Calaveras formation. Three adits and some shallow shafts were run many years ago.

In 1933-34, H. D. and Vivian Dibble et al. leased the claim and erected a plant containing a 40-ton Herman ball mill, classifier, and flotation cells. Some ore was crushed in 1934.

Black Hawk mine is in SW¼ sec. 35, T. 2 N., R. 15 E., 2 miles west of Soulsbyville. Mineral rights on 59.95 acres are assessed to Organized Gold Mines Company, Limited, c/o John D. Hoyt, 756 South Broadway, Los Angeles.

The vein strikes northeast and dips 75° to 85° SE. in granodiorite. A vertical two-compartment shaft was sunk 200 feet in 1906 and levels were opened at depths of 100 and 200 feet, but there is no published record of production at that time.

In 1932, the above company was organized, and reopened the workings. A small ball mill was installed to mill ore that was reported to have been developed when work stopped in 1907. Several small stopes were opened, one 40 feet long by 12 feet high on a 10-inch vein on the 200-foot level, and one 30 to 40 feet high from the north drift on 100-foot level, where ore was mostly removed for the length of the drift, 125 feet. On the 200-foot level, the north drift is 94 feet long, and the south drift had previously been run over 125 feet. T. E. Massie, who sampled the mine in August 1937, found the vein ranges from 3 inches to 23 inches but averages 8 inches on the two levels, with great variations in gold content.

Black Jack and *Ida Della* quartz claims are near Eagle Creek in the Jupiter district. In 1947 they were deeded to John C. P. Skottowe, 1317 North Curson Avenue, Hollywood 46, with whom Luigi Rosselli, 6075 Franklin Avenue, Los Angeles 28, is associated, in Black Jack Gold Mining Company, Ltd. Some work was planned in 1946, and machinery was to be installed, but no recent activity has been noted.

Bonanza mine is in the city limits of Sonora. It has been described in many of the past publications of the State Mining Bureau to which reference may be made. None of these, however, give any details of the famous pocket discovered in 1879. A contemporary account, published in the Independent at Sonora for the week of Sept. 27, 1879 is of sufficient interest to warrant repeating in part, as follows:

> "On September 27th, Wells, Fargo Co., shipped from Sonora several hundred pounds of gold bars, the product of a mining claim in town. All kinds of rumors were afloat as to weight and value, some stories going as high as 600 pounds, and $90,000 in value. The truth, however, in this instance, is more startling than rumor. The amount shipped, as the express receipt shows (as exhibited to a friend of ours by one of the lucky parties), is $189,000 and the weight 820 pounds. Some $50,000 was shipped at different times, not long since, and about $26,000 previously, making a grand total taken out, that is known, of some $265,000, or over a quarter of a million dollars inside of seven months. The claim is located on Gold Hill, in Sonora, at the head of Washington Street, a few yards west of the Episcopal church, the tunnel being on a level with the street. Charles Clarke, Joseph Bray and James G. Divoll are the partners, the two former only working in the claim, with no other assistance. This hill has been celebrated for the amount taken out in early days, and has been repeatedly prospected for years since by parties who hoped to find another bonanza. The gulches running from it have also been fabulously rich—especially the run south, crossing the old Condit lot (since mined out with big results) and continuing down through the center of Washington Street. Several companies have, at different times, proposed to tunnel down the length of this street, but it was never done, as no arrangements could be made with the city. . . . It remained for the latter parties, named above, to be more fortunate. These gentlemen have had much experience in quartz mining, and believing they could find a bonanza, started in some months since, and now have a big reward for their faith and well directed labor. They are very reticent about details, and it is difficult to get at all the facts the public would like to know. The quartz yielding the last shipment of $189,000 was taken out by two parties, inside of a week, about two months ago, and they have since been engaged in pounding it out in mortars and running it into bars—the tunnel in the meantime being fastened by an iron gate and heavy locks; no admission given to anyone. The bullion is very fine, and will coin near $20 per ounce at the Mint. Sheriff Yancey and Assessor Monahan went down with the stage as a guard, and no one outside knew anything about the matter until a day or two later. They were instructed not to stop at Copperopolis, but to go on until they struck the up Milton stage. It was necessary, however, to stop at Copperopolis to brace up the stage, as the immense weight stored in the iron safe under the center seat caused the stage to sag in the middle."

Buchanan mine is in secs. 26 and 27, T. 1 N., R. 16 E., 4 miles southeast of Tuolumne in an air-line. This old property was fully described in reports of the State Mineralogist for 1888-92 and was productive until 1894. Afterward, it lay idle and abandoned until 1932 when Buchanan Gold Mines, Inc. was organized, but the company lapsed early in 1935. J. A. Cook, who had been connected with the company, then leased the claims and continued work in a small way until a fire destroyed most of the buildings in September 1939. Some ore was mined from the adit level (100 level) and 200-foot level. Apparently the old deeper workings, (which included an inclined shaft and an inclined winze 380 feet deep below the 500-foot level) were not reopened. A mill of 10 tons capacity was operated until late in 1936 when capacity was increased to 25 tons a day. The remnants of ore found were said to yield $5 a ton. At present (May 1948), equipment is being put on the property.

Buckeye group of three claims joins the Buchanan mine on the south, extending 4000 feet or more down the slope southward toward the South Fork of Tuolumne River.

Columbus mine is in secs. 31 and 32, T. 2 N., R. 16 E., about half a mile southwest of Cherokee. P. Bacharach, 595 Marina Boulevard, San Francisco, bought the mine and all equipment in December 1938, after the last period of operation, and sold the equipment in 1939.

This mine was worked off and on prior to 1912, then lay idle until 1933 when Columbus Gold Mining Company began work. They operated until early in 1938. The inclined shaft, which had been sunk 400 feet by previous operators, was deepened to 900 feet with levels 100 feet apart. Crosscuts were run to the hanging-wall vein, on which several thousand feet of drifts, raises, winzes, and stopes were opened. Milling started in November 1933 with 10 stamps to which a ball mill, classifier, Bendelari jig, flotation cells, and cyanide plant were later added, raising the capacity from 30 to 70 tons a day.

The best ore was evidently produced in 1934 from a depth of 400 to 500 feet on the south side of the shaft where ore 3 to 4½ feet wide showed in places considerable free gold. Over 6000 tons milled in 1934 yielded $9 to $12 a ton. Up to half the gold was saved by amalgamation. Sulfides (pyrite, galena, and zincblende) formed 1.3 to 1.5 percent of ore, and during that year averaged about $250 a ton. Later the grade of ore was lower, and termination of work by the company in 1938 was reported due to this. After the company quit, a group of miners who had been employed there operated the mine and mill for a short time.

The lode on this property is locally claimed to be the north extension of the Eureka-Dead Horse system. It shows a massive outcrop 60 feet wide with a filling of quartz and schist in which hanging and footwall veins occur, with a footwall of hard ''diorite'' and hanging wall of hard ''mica schist'' in the granodiorite country rock. The old operations prospected for 700 feet to the north of shaft, and produced $5 ore (old gold price). The later work opened 600 feet in length to the south.

Confidence mine contains 70 acres and is in W½ sec. 10, T. 2 N., R. 16 E., M.D., at Confidence.

This was one of the larger producers among the east belt mines. It was discovered in 1853, and most of the early day production, claimed to have amounted to $3,250,000, was made prior to the time when any systematic production figures were kept. Beginning in 1868, from 10 to 20 stamps were operated for many years. A second period of operation began in 1896 and extended to 1912. During this time, 20 to 30 stamps were operated, and considerably over $1,000,000 was produced. Most of the production came from above the 810-foot level (inclined depth). In the first period, much of the ore carried an ounce or more of gold per ton, and loss due to sliming of sulfide was rather high. When the later plant was built in 1896, cyanide treatment was installed and recovery was claimed to be improved on ore that yielded from $3 to $12 a ton (old gold price). The concentrate was high in gold content, carrying 8 ounces gold or more per ton, but the quantity saved was small during this second period, although the ore was generally regarded as quite base.

The vein varies from 1 foot to 15 feet wide, strikes N. 14° W., and dips 18° to 30° E. in granodiorite. A dike accompanies the vein. A depth of 1210 feet on an average inclination of 30°, equal to about 540 feet vertical, was reached in two shafts and a winze. The north or new shaft, about 1200 feet from the old one, was deepened by Confidence Gold Mining Company (1917-20), who installed a plant of 150 tons capacity but did little milling.

In 1935, another Confidence Gold Mining Company was incorporated and the mine was reopened and equipped with a 100-ton milling plant, including flotation and cyanide equipment. Tahoe Treasure Mining Company also advanced a large sum of money. Work was done between the 500-foot and 1100-foot levels south of the north shaft. The operators claimed to have enough ore for 2½ years, but work stopped after a few thousand tons was crushed in 1937. Dilution from the wall rock, which could not be controlled, was given as the reason for closing.

Criss Cross and *Relief patented lode claims* are in the NE¼ sec. 26, T. 1 S., R. 15 E., 1 mile from Priest. Saul Morris, 156 East Adams Street, Stockton, is the owner. These claims are in the same pocket belt as the Eureka and Grizzly. The Calaveras slate, containing some zones rich in pyrite and there called ''metallic slates'', carry two systems of quartz veins and seams. One set, nearly flat, dips slightly west. The second set strikes N. 30° E. across the schistosity of the slate, and dips 70° SE. The metallic slate zones are separated by dikes.

In the southern part of this mine, pockets have been found in the flat quartz veins. In the northern part, however, the gold has been found in the steeply dipping veins, in the ''metallic'' slate zones. The claims have not been active recently.

Crystal Springs placer mine is in the SE¼ sec. 22, T. 2 N., R. 14 E., half a mile west of Shaws Flat, on the Table Mountain channel. It was known in the early days as one of the profitable mines on the channel. The subsidence of the overlying lava caused by extensive breasting is supposed to have stopped work during the sixties and the property lay idle until 1888, when it was reopened and worked at least until 1896 by F. McTarnahan, who drove a bedrock adit through slate from the west side of the ridge. Early in 1948 a few men under the supervision of Thomas Skaggs were engaged in reopening the mine.

Densmore mine contains 59.43 acres extending southeastward from Stanislaus River up the steep east slope of the canyon in sec. 4, T. 2 N., R. 14 E., to the Columbia and Parrotts Ferry road 2½ miles from Columbia. It lies in granodiorite and the vein dips 60° NE. The average width of vein is 5 feet, although it swells to 25 feet or pinches down to 1 foot. The gold is principally associated with pyrite, marcasite, galena, and other sulfides.

The first reported production was in 1899-1900 by William Francis, who shipped rich sulfide ore that yielded $26,000. Hayward and Lane and Densmore Consolidated Mining Company worked the mine from 1900 to 1906, and used a 14-stamp mill, concentrators, and cyanide plant to treat ore from a shoot about 200 feet long and 400 feet deep, which was found in No. 3 adit, connecting with a shaft 500 feet deep. About 19,000 tons was produced during this period. From then until 1936, the workings were extended but little ore was milled. More ore was claimed to have been found south of a fault which had terminated the first ore shoot. In 1936, an R.F.C. loan of $20,000 was obtained by Densmore Gold Mines, Inc. who worked the mine for the next several years. It had been prospected and worked previously through adits numbered 1 to 5, No. 1 being 100 feet above the river, No. 3 (the old working entry) being caved, and No. 5 or Ogden adit, 952 feet long. A new shaft had been sunk 120 feet in the New York ore shoot, ahead and south of the face of No. 5 adit, with which it was connected by an inclined raise. The work after 1936 consisted chiefly of advancing No. 5 adit and mining ore between it and the south shaft. A 50-ton ball mill with a Bendelari jig, Deister table, and Fagergren flotation cells was installed late in 1937 and operated part time in 1938 and 1939. In 1938, a total of 1570 tons of ore was milled, from which concentrate shipped to Selby smelter yielded 2001 ounces of gold and 975 ounces of silver. In April 1939 the property changed hands and the new operators built another 50-ton mill and cyanide plant which began operation in July 1940, but was shut down in February 1941; in July 1941 Densmore Mines took over and operated during the rest of the year. No. 5 adit by this time was 1300 feet long and was claimed to be in good ore 4 feet wide.

Eagle Shawmut mine was idle from 1926 to 1936. H. G. Miller and George W. Clemson took it over in 1936 and operated from 1938 to October 1947; Daniel C. Peacock was manager. During this time a gross production of about $2,000,000 was made from 730,000 tons of ore, with profit to the operators after the early period of experimental work in mining and metallurgy. The previous production, 1897-1926 inclusive, was nearly $5,380,000, making the total recorded gross output about $7,380,000.

The ore mined by Miller and Clemson has all been taken from above the adit level (No. 2) except for 1000 tons. All three shafts are caved.[9] This adit is a crosscut 1200 feet long through the footwall slates to the vein, then following vein both ways a total of 1800 feet. The ore came from below old shallow workings, where the east and west veins had been mined by glory holes as well as stopes. The walls were consequently broken and caved. Block caving was adopted, and twenty-two grizzlies and four mucking chambers were used. Where the ground was so crushed that raises, grizzlies, and service drifts could not be maintained, the broken rock was drawn from the level by installing concrete mucking chambers and loading ore with mucking machines directly into cars. If ore would not move, it was started by blasting. The largest year's production was in 1943, when 172,756 wet tons, (or 168,118 dry tons if 5 percent moisture content is estimated) was mined. After 1943, only half or less of the mill capacity was used for gold ore, as copper and zinc ore from the Penn mine in Calaveras County was treated at Shawmut. The total mill capacity was 500 tons a day on the Shawmut ore, but after 1943 about 200 tons a day or less of this ore was crushed.

In 1940, about 28 percent of the gold and 23 percent of the silver were recovered in bullion from jig and table concentrate. In the later work the percentage of such free gold dropped to 5.3 percent in 1942 and to 2.1 percent in 1945, with silver even lower. The percentage of concentrate recovered ranged from 2.2 to 3 percent of ore milled. The net recovery of gold for the entire operation averaged 83 percent of assay value. Figures of annual production for a number of years have been published, covering over 500,000 tons production. The average recovery for this was $2.614 gold and silver, with gold at $35 and silver at $0.7111. The silver amounted to only 2 cents a ton. A very little copper, averaging 0.11 of a pound per ton of ore, was reported.

The milling equipment included a Telsmith 16B gyratory crusher, Symons cone crusher, two ball mills, classifiers, nineteen flotation cells,

---

[9] Logan, Clarence A., op. cit., 1934, pp. 162-164.

24- by 24-inch Pan-American jig, 4- by 8-foot Straub table, filters, etc. Ore was ground to pass 60 percent through 200 mesh and after jigging and table concentration to save free gold, was conditioned to a pH of 8.2 to 8.4 with soda ash in which was mixed 3 pounds of $CuSO_4$ to 100 pounds of soda ash. American Cyanamid Aerofloat Reagent 208 was used as a safeguard to save gold that had escaped the jig, and Reagent 633 was used to depress carbonaceous material in the ore. A. C. Reagent 301, a xanthate of higher petroleum alcohol, was used as a promoter for the pyrite, and a very little pine oil for frother. Concentrate, which carried from 2 to 3 ounces gold per ton, was hauled by truck to Selby smelter. The fact that this type of concentrate was needed there made it possible to operate the mine during the war. But the war prevented the necessary development of the mine, and high and increasing costs in October 1947 made it unprofitable to continue. All work was suspended and equipment is being offered for sale.

Daniel C. Peacock estimates that considerably more ore remains in the mine, and of better grade, than has been worked since 1938. Between the No. 2 and No. 5 levels diamond drilling was done by Miller and Clemson. This indicated the presence of such ore, besides which there remains a good-sized block of ore above the level of No. 2 adit in the south part of the mine.

In June 1948, old chlorination tailing from this property was being hauled to the railroad at Chinese Station and being shipped in gondola cars to Selby smelter for use as flux.

Erin-go-bragh and *Cloudman patented mines* are in NE$\frac{1}{4}$ sec. 27, T. 1 N., R. 14 E., M.D., a quarter of a mile southwest of Stent, on the Mother Lode. Estate of R. C. Bach is the owner; M. R. Bach, 28 West Vine Street, Stockton, is administrator. The area is 31.21 acres, covering 2000 feet in length.

Little work was done in early days on these claims. In 1923, J. L. Bryson and associates sank a shaft 92 feet deep but closed down before their crosscut reached the vein. Bach purchased the claims in 1925. In 1929, L. M. Thornburgh, Atascadero, took a lease and option, sank a shaft 250 feet and ran 1100 feet of drifts and crosscuts on the 200-foot level, but made no recorded production. California Standard Gold Mines Corporation was incorporated early in 1933 and developed the middle vein south of the shaft on the 200-foot level where they claimed to have an ore shoot 160 feet long, and as much as 35 feet wide. The shaft was sunk to 435 feet and a level was turned at 400 feet. Considerable work was done on this level including a number of crosscuts, and ore was claimed to have been found in each. For a time this level supplied 30 to 50 tons of ore a day from crosscuts, drifting, and stoping.

A ball mill and flotation plant were put in operation March 1, 1936. In the ensuing 14 months a total of 35,183 tons was milled, yielding $223,909.76. Most of the gold was in the sulfide, which was practically all pyrite. Concentrate saved was from 7 to 8$\frac{1}{2}$ percent of ore milled, and assayed about $58 a ton. This was not the entire tonnage milled, as the company continued work until July 1, 1937. Part of the ore came from an open pit south of the shaft, where a width of about 20 feet was worked, and ore was dropped to the 200-foot level and hoisted from the shaft. It was claimed four miners produced 100 tons a day or more from this pit. Concentrate was shipped to Selby smelter. According to a company report, the cost of transportation and treatment of concentrate, and the reduced price for gold paid by the smelter lowered the average net amount realized on the above ore to $5 a ton. Recovery was claimed to be 90 to 95 percent of assay value.

After this company quit, the mine lay idle until late in 1938 when Del Gold Company took it over and made some production in 1939 from ore mined on the surface with a power shovel. Mr. M. R. Bach states that his father received royalty on a total production of $282,000 from the mine.

Marion Gold Mining Corporation, Route 1, Box 227E, Lathrop, held a lease for several years up to 1948. They have done no mining on the claims and have recently begun removing buildings except the headframe. Rails, machinery, and pipe had been taken out previously, and water has filled the workings. R. C. Bach reports that mine maps indicate a substantial tonnage of ore is left above the 400-foot level.

Eureka and Grizzly lode claims were located in 1894 by Ed and Charles Harper, Box 45, Big Oak Flat. The owners have worked the claims intermittently ever since as pocket mines, and still hold them. The land adjoins the Criss Cross and Relief patented claims on the southeast in E$\frac{1}{2}$ E$\frac{1}{2}$ sec. 26, T. 1 S., R. 15 E., near the state highway on Priest grade, 1 mile from Priest.

The country rock is Calaveras slate and interbedded tuff, striking northwest and dipping steeply northeast, nearly vertical. In places favorable for pockets the slate carries considerable pyrite. The slate contains series of quartz seams and veins, some vertical and some nearly horizontal, but rolling slightly, probably due to minor movements. In this property, pockets were first found by following a ''trace'' to one of these flat veins. Harper Brothers state that the most productive vein in the mine did not outcrop, but was discovered after running short drifts on the first vein and sinking shallow winzes. The second flat vein proved productive for a length of 200 feet. The working of several such flat veins by adits and stopes in places only a few feet apart vertically, caused heavy and weak ground which required close timbering with stulls in places. All drilling has been done by hand. The longest of the series of adits has been driven nearly 300 feet.

Some of the veins, which occur at intervals as narrow as 8 to 10 feet apart (in both the flat and steep-dipping series) are 2 feet wide in places. The largest single piece of gold, taken out in 1946, was 6 inches wide by 13 inches long and weighed 67 ounces. According to the finder, this beautiful specimen, now on display in Sonora, was discovered in a bed of loose, clear quartz crystals and talc. A few such quartz crystals have been found with included gold. The total production has been substantial.

Experimental mine (on Experimental Gulch placer mine, patented) is lot 3 in NW$\frac{1}{4}$ sec. 1, T. 2 N., R. 14 E., 1$\frac{1}{2}$ miles northeast of Columbia. It is assessed to Forrest W. Schoettgen et al., Columbia. Three unpatented lode claims and a mill-site have been held also.

The vein was found 6 feet below the surface during placer mining and the first stamp mill, 8 stamps with square wooden stems, was erected in 1854. The mine has been worked intermittently ever since. The vein strikes N. 20° W. and dips 40° E. The hanging wall is hard dolomitic limestone with caverns, many of which contain water and mud. The footwall is also limestone in which there is a series of diorite dikes striking across the course of the vein and dipping steeply. Ore shoots occur at the junctions of the vein and dikes. In the past, ore was 2½ to 3½ feet wide. The ore in depth carries free gold, pyrite, galena, and chalcopyrite.

The principal workings are an inclined shaft on the vein, connecting at a depth of about 630 feet with a drain tunnel over 3000 feet long, below which winzes have been sunk 300 feet apart on the Shaft and Cellar ore shoots, and levels have been opened.

Since 1928, several thousand tons of ore has been mined and milled, principally by Shoestring Mining Company between 1936 and 1940. In 1946, United Gold Mining Company, Inc. worked on the property and milled some ore. There is a five-stamp mill at the tunnel portal.

No complete record of the production exists because of the long period over which work has extended, but it has amounted to several hundred thousand dollars. In recent years, recovery has ranged from $5 to $15 a ton.

Fifty-five mine (Little Florence, Mother Lode Extension) contains 20.65 acres in sec. 22, T. 3 S., R. 15 E., 3 miles south of Blanchard. It has been worked for short periods by various companies and has been a frequent subject of court action. Lewis H. Bach, Sonora, is trustee (1946-47).

It is claimed to have been found in 1855, but the first available record is for 1924, when some ore was shipped by W. R. English and associates, Los Angeles. The shaft was then 50 feet deep. English Mining Syndicate was formed in 1925, and small production was reported that year. In 1927, a total of 200 tons of $10 ore was milled. In 1928, Mother Lode Extension Mines Company had the property, but was succeeded in 1931 by Calaska Gold Mines, Limited, as the operator. During this period, production continued on a small scale. The shaft was sunk to 200 feet in depth and 240 feet of drifts were run. The 10-stamp mill was operated only part time. Disputes and litigation between principals led to appointment of a receiver in 1934.

Golden Gate Mines, Incorporated, was organized to work a gold quartz prospect on the Williams Ranch in sec. 11, T. 1 N., R. 15 E. R. K. Weaver is president and R. C. Cook treasurer, 1414 29th Street, Sacramento. Little work has been done on account of high costs since the war. A 1½ compartment shaft has been sunk 40 feet on a vein 18 to 20 inches wide, which prospects well, according to tests reported by R. C. Cook. An old adit 140 feet long would have to be extended more than 400 feet to reach the vein. A hoist, blacksmith shop, and tools are on the property.

Gross and Street mines (Gross Consolidated and Shaw and Schollar or Street patented claims) are in secs. 29 and 30, T. 2 N., R. 14 E., on the south side of Jackass Hill half a mile north of Tuttletown. The land is assessed to Gross-Street Mining Company, c/o Cecil R. Haden, 914 Union National Bank Building, Houston, Texas. Since 1946, Hawood Corporation, composed of Cecil R. Haden and C. E. Wood, Jamestown, have been prospecting the claims; milling of ore was begun in May 1948.

The shaft now in use on the Street was sunk by previous operators to a depth of 330 feet on 70° incline and levels were turned at 200 and 300 feet, the principal drift being one 900 feet long N. 30° W. on the 300-foot level. On the parallel Gross claim, an adit about 30 feet deep was run on a lead striking N. 34° W. Between 1898 and 1911 about 2500 tons of ore was produced by the late Fred Sutton and associates. Most of this came from the shallow adit workings on the Gross and from a 50-foot winze there. About 1920, Gross-Street Mining Company did some work but made no production.

The present operators reopened the Street shaft to the 300-foot level and ran a diamond-drill hole westward to the Gross vein on that level. This was followed by a crosscut 700 feet long on the 300-foot level which struck the Gross vein north of the drill hole. On May 15, a drift had been run 60 feet south and 75 feet north from the crosscut on this vein. It is a stringer lead of quartz and calcite in gray-green amphibolite schist. The pyrite content is quite high, as is usual in this district. Pyrite cubes up to 1 inch square were seen, and larger ones are reported. A thin coating of gold can be seen in some cases on the faces of these cubes and some cubes contain quartz. Clear quartz crystals also occur. All rock from the drift 6 feet wide was going to the mill at the time of visit, and was yielding satisfactorily. A raise was also being put up for a second exit. The ground stands well and requires little timber. Five men work one shift underground. Mine equipment includes a Vulcan single-drum hoist with 30-horsepower electric motor, an air-cooled Ingersoll-Rand motor compressor of 460 cubic feet capacity operated by 75-horsepower electric motor, a smaller compressor, air drills, and mucking machine.

Ore is hauled by truck to a rented mill on the Marryat mine, half a mile south. This mill, run by electric power, contains a 9- by 15-inch crusher with a 30-horsepower motor, a 50-ton Hardinge mill with 60-horsepower induction motor, single drag classifier, Pan-American placer type jig, and three Fagergren flotation cells. At present it is operated 16 hours a day and the flow sheet has not been completely worked out, but it appears to be making a very good recovery. The jig yields a coarse pyrite concentrate and some free gold. For flotation, American Cyanamide Company's reagents 301 and 208 and frother B23 are used. C. E. Wood is in charge and a total of 10 men are employed in the mine and mill.

Ham & Birney (Hamilfield) mine (including Hart & Jacobs claim) in sec. 4, T. 2 N., R. 15 E., 7 miles by road northeast of Columbia, is an example of a long-lived small mine that has been a producer at intervals for about 60 years. The vein strikes northeast and dips 25° to 30° SE., and is 1 to 5 feet wide in the Calaveras schist. It runs along the slope of a high ridge and has been mined through a series of adits, as well as a shaft sunk 256 feet at an altitude of 3400 feet. This discovery shaft is claimed to have yielded $52,000 previous to 1900. A 10-stamp mill was put in operation in 1895 and $13,000 production was reported that year, but most of the production since has been from pockets, the value of which in several cases is not known, as the production of a number of these small mines was often reported in a lump sum. The work of Callahan & Bleck produced about $5100 in 1924 and $4000 in 1925 from an ore shoot previously credited with $10,000 production several years before. The total production has probably been about $100,000. The last work was done in the late 1930's by D. B. Woodruff, who in 1938 milled some ore that contained about $10 a ton.

The Ham & Birney patented claim lies on the higher ground to the southwest, with the Hart & Jacobs patent adjoining on the northeast and extending across Five Mile Creek. The wallrock is Calaveras schist and quartzite, and a dike accompanies the vein. Sulfides and silver are present in sparse quantities. The four upper adits were run in early days and were reported to be each about 380 feet long. No. 4 adit was later extended to 500 feet. Nos. 5, 6, and 7 were shorter. The series of seven adits, ranging from 88 to 116 feet apart vertically, explored a vertical range of 600 feet below the bottom of the shaft, in a shallow outer block of vein parallel to the surface.

Harvard Gold Mining Company (926 Crocker Building, San Francisco, California, P. R. Bradley Jr., president) holdings include the Trio (Harvard), Mooney quartz mine and millsite, McCann, Pacific, Sobrante, and Vulture patented claims covering nearly a mile along the strike of the Mother Lode, 1 mile southwest of Jamestown.[10] Since 1935, diamond drilling and other investigations of the property have been carried on. About 5500 feet of diamond drilling was done and two reports were prepared (1935-37) for the owners, which purported to show that a substantial tonnage of ore, of about the same gold content as that formerly worked, remained in the upper part of the mine. The increased price of gold had made this ore of possible interest.

In November 1938, the present company, in which Alaska Juneau Gold Mining Company is listed as the principal stockholder, began work on the property. The workings were reopened to the 500 level. A total of about 31,000 feet of diamond drilling, said to be the largest private contract for such work in California, was done in the next 2 years. About 16,000 assays were made. The drilling required some underground work such as reclaiming No. 1 shaft, and drifting and crosscutting, principally on the 200 level. Some crosscuts were also run on drill holes and the rock from these was hauled by trucks to the mill on the Pine Tree mine, Mariposa County, for milling tests.

A large tonnage of low-grade ore was indicated by this work and the management believes this can be handled profitably under more favorable economic conditions, but on account of recent high costs all work except maintenance has been suspended. Plans have been made for possible operation at the rate of 500 to 1000 tons daily by methods similar to those followed at the Alaska Juneau mine, but their execution will depend on a recession in costs of labor and materials.

Hidden Treasure mine is on Bluett's Point, 3 miles north of Columbia and contains one full lode claim and a fractional claim 400 feet long. George L. Trask is the owner.

The vein strikes N. 55° E. and dips 65° SE. in Calaveras schist. Gold pockets occur where seams from the hanging wall cut the vein. These seams may be ''rusty'' black, or filled with quartz. The vein was 2½ feet wide in the shallow workings opened in 1931 by Sherman Wetmore, who mined and crushed by hand enough specimen ore that year to sell over $8500 in gold. The mine has been worked irregularly since. During 1946 and 1947 H. C. Keenan and Harry Gibson, Columbia, have been operating under a lease. In 1946, production of 130 ounces of gold was reported from 5 tons of ore crushed in a small mill.

Junction mine is in sec. 1, T. 1 N., R. 15 E., 1 mile south of Soulsbyville. Junction Gold Mines, Inc., 156 Montgomery Street, Room 203, San Francisco, holds a lease of mineral rights on parts of the Yost and Armario ranches, but has not operated since 1942. E. H. Minor is in charge locally.

The Junction shaft was sunk in 1896-98. The present company reopened it, and extended the south drift to 691 feet and the north drift to 150 feet on the 200-foot level. Mr. Minor states that the 300-foot level shows an ore shoot 180 feet long.

---

[10] Logan, C. A., op. cit. 1934, pp. 165-166.

In May 1942, the company officials released a report of assays of samples taken over a length of 177 feet on the 200-foot level, indicating a width of good ore ranging from 2 inches to 2½ feet. Another lot of very encouraging assays from the same level were reported in November and December of 1942. No ore has been milled by the present company but some stoping to a depth of 60 feet is said to have been done 50 years ago. There are some small buildings housing a single-drum hoist, a 450 cubic foot Ingersoll Rand air compressor, electric motors, and tools. The shaft and workings are kept dry by pumping. The vein is in granodiorite.

Jumper mine at Stent, in secs. 27, 35, T. 1 N., R. 14 E., has been active for short periods several times since 1934. It is grouped with the New Era and Golden Rule. Plans were made several times for working by glory hole. In 1939, Brighenti Brothers unwatered the Jumper to the 600-foot level and planned to work with power shovels. In 1940, Lobicasa Company, who have been interested principally in surface placer mining, mined and milled 2585 tons of ore which yielded $5.25 a ton.

Late in 1946, R. E. Fitzgerald (Jumper Mining Company) erected a mill of 100 tons capacity and did some work.

Lazar pocket mine is on the east side of Woods Creek near Browns Flat, 1½ miles north of Sonora. While it is claimed to have produced pockets previously, the record before 1929 is not available. From 1929 to 1931 inclusive about $11,000 in gold, much of it beautifully crystallized, was sold by Lazar Vucasovich & Company. In 1933 it was equipped with a hoist and air compressor and it continued productive through 1937 under various lessees. A pocket of gold worth more than $5000 was reported late in 1934; and in 1935 a pocket said to contain gold worth more than $13,000 was found. The same year the dump was milled with good returns.

The mine was opened first by an adit, from which a winze was sunk 90 feet; a drift was run from the bottom of the winze.

Little Gem (Harris) mine is a fractional claim of 10 acres in sec. 16, T. 1 N., R. 14 E., M.D., covering a length of 550 feet along a vein in the hanging wall of the Mother Lode on the east side of the Harvard (Trio) mine. The principal work was done in the eighties and nineties by W. N. Harris and later by the Henslee Brothers. An adit gave a depth of 70 feet and a shaft and incline extended 85 feet deeper. Much of the production, however, came from open cuts on schist ore. A 10-stamp mill was run by water power, and mining and milling cost $1.25 to $3 a ton. Gold was saved by amalgamation on inside and outside plates, and no equipment was used to recover sulfide. The ore was claimed to yield from $3 to $7.50 a ton but few production figures were ever published. Production of $8000 in 1890, $19,238 in 1891, and $5000 in 1897 was reported, but no figures are available for other years, although a total of $200,000 has been claimed.

Longfellow mine is in sec. 30, T. 1 S., R. 16 E., at Big Oak Flat. The vein strikes east and dips 50° S. in Calaveras slates. The period of principal activity was between 1889 and 1907. Some ore was produced and milled in 1913-14, and again in 1930-31. Previous to 1907, the average grade of ore was $6 to $10 a ton but the later yield per ton was much lower. The shaft reached a depth of 900 feet on 30° incline, with nine levels, the first eight being 100 feet apart, and lowest at 850 feet. The veins were prospected for 500 feet east and 400 feet west on the 400-foot level; other levels were shorter. Stoping was carried on east of the shaft from the 600-foot level to surface. There are two veins, about 50 feet apart, the footwall vein being 10 feet wide and the hanging wall vein 5 feet wide. The ore contains free gold and 1 percent of auriferous pyrite. The ore shoot was reported to be 100 feet long. The Mack claim adjoins on the east, and the two have at times been held and worked together.

In 1935-36, California Gold Lode Mines, Ltd., sold considerable stock and did some work on the Longfellow. They were succeeded in 1937 by Metallic Mines who worked intermittently through 1938. Both these companies had a mill in operation part time on dump material. A 10-stamp mill crushed the dump rock to 8 mesh and delivered pulp to an Akins classifier, from which overflow went to a Bendelari jig. The jig concentrate carried $45 a ton in gold. Coarse pulp from the classifier was ground in home-made tube mills. Six flotation cells treated the pulp from the jig and made a concentrate worth $230 a ton. Both concentrates were reground and cyanided with a good extraction. Only 2000 tons were handled in 1938 and no further production was reported.

Mack mine (Big Casino) is at Big Oak Flat, in N½ sec. 30, T. 1 S., R. 16 E. Frank E. and Marie A. Pagett, 2624 Rawson Street, Oakland 2, are the owners.

No work has been done recently underground at this mine, which has two old shafts, 700 feet and 450 feet deep, and six levels in the deeper shaft. About 1938, however, a pocket which is believed locally to have produced $16,000, was taken from the surface of the claim and caused local interest because of legal action taken against its finder, who was working the mine under lease.

Mohrman mine is a patented claim of 14.19 acres in SE¼ sec. 30, T. 1 S., R. 16 E., half a mile south of Big Oak Flat. Joseph Musante, et al., Groveland, and Fred Musante, 2417 Bryant Street, San Francisco, are the owners. The vein strikes north and dips 30° to 35° E. in Calaveras slate and mica schist. It averages 4 to 5 feet wide.

This claim has been worked off and on as a pocket mine for over 40 years. Quartz taken out in the course of the search for pockets has been crushed from time to time in a two-stamp mill. Such small tonnages were worked in 1918-19, in 1929-34 and in 1938, when 475 tons of ore yielded 168 ounces of gold. The total production has been about $40,000. The workings consist of a series of adits, the longest 300 feet and another nearly as long. A winze was sunk 100 feet from the highest adit. The best ore is in black slate, according to Harper Brothers, who have worked the mine; they report small amounts of telluride.

O'Hara (Franklin) mine is in sec. 25, T. 2 N., R. 14 E., 1 mile north of Sonora and west of Woods Creek. This mine is locally credited with a gold production of over $100,000 from pockets, but little has been published about it. It was worked by the O'Hara family, owners, for about 40 years.

The main shaft was sunk 800 feet on an incline of 15° following the dip of a green dike at the contact of Calaveras slate and limestone. Levels were turned 50 feet and 100 feet apart and drifts were run usually only 50 feet each way on the vein or dike which strikes N. 85° E. and dips northwest.

Ryan group of five patented and nine unpatented claims lies in sec. 1, T. 2 N., R. 16 E., and sec. 36, T. 3 N., R. 16 E., 1½ to 2 miles east of Sugar Pine. The group includes the Green Consolidated and Ryan patented claims and other quartz and placer claims. John T. and Philip M. Ryan, Sonora, are the owners.

The principal work done in past years was on the Green where the vein strikes north and dips 30° E. in granodiorite. The old shaft was 400 feet deep. The Ryan adjoins the Green on the south, and there is also a north extension of the Green. The Mount Moriah patented claim adjoins the Green on the east and is parallel to it. Operations have been carried on irregularly since 1928, when ore was taken from a tunnel then 250 feet long on the O. J. O. claim, where a vein 2 feet wide was reported to prospect well. The only important production reported was in 1940 when 1700 tons taken from the Ryan mine yielded 991 ounces of gold and 114 ounces of silver in bullion, and 20 ounces of gold and 30 ounces of silver from concentrate.

Snell mine is lot 40 in sec. 7, T. 3 N., R. 15 E., 13 miles north of Columbia. It is best reached via Vallecito and Stanislaus power house. The owners are Estate of Caleb Dorsey (half interest) c/o J. Dorsey Ewing, 1125 North El Dorado Street, Stockton, and Miles Mitchell (half interest) P. O. Box 1137, Oakdale.

Early in 1948, Mitchell and a few associates were working part time to reopen old caved workings. The claim was worked over 80 years ago. There are two shallow shafts. Ore was hauled to an arrastre.

Soulsby Belle mine contains 40 acres in SW¼ NE¼ sec. 30, T. 2 N., R. 16 E., 1½ miles by road northeast of Soulsbyville at 3000 feet elevation. The owner is Soulsby Belle Mining Company, c/o Harry Bahl, 1600 East 15th Street, Kansas City, Missouri. John Kelly, Soulsbyville, is resident agent. The mine is near the east side of the granodiorite in which the Black Oak and Soulsby mines were found. The vein strikes north of east and dips south, and the shaft followed it.

Production was started in 1929 by A. P. Hoffschneider with a few tons of high-grade ore. A company was formed and produced a few hundred tons of ore before being dissolved in September 1932. The shaft was then 192 feet deep, and five levels, from 26 feet to 153 feet deep, had been run. The present company took over in 1932 and worked until June 1937. The shaft was deepened to 445 feet and levels were turned at 225.7, 319, 356 and 445 feet in depth. Drifts were run 50 feet east and 150 feet west on 225-foot level; 210 feet east and 100 feet west on 319-foot level; and 100 feet east and 120 feet west on 445-foot level. A series of diamond-drill holes, the longest 163 feet, was run north and south from the 319-foot level.

Several small ore shoots were stoped, and yielded up to 2 ounces gold per ton. According to John Kelly, who was manager, the ore was 1 foot to 14 inches wide, and was hand sorted. There is a 65-foot wooden headframe with strap iron rails and ore bucket. At present the mine is full of water. About 12,000 gallons of water was pumped daily while the mine was being operated. Galena, zincblende, and pyrite carry much of the gold.

The mill building, covered with galvanized iron and in good repair, houses an 8- by 10-inch rock breaker, 3- by 4-foot Hendy ball mill of 25 tons daily capacity, drag classifier, gold catcher, 64 square feet of silvered plates, a 15-foot Wilfley concentrator and clean-up barrel. A smaller building contains a 310 cubic foot Ingersoll Rand air compressor with 50-horsepower three-phase electric motor, another older compressor and several motors. In the shop building are a drill sharpener, two forges, and tools.

The company has been waiting more favorable conditions to resume work.

Stockton pocket mine, lying a few hundred feet southeast of the Sierra Railway depot in Sonora, in sec. 6, T. 1 N., R. 15 E., has been worked irregularly in a small way in recent years through a shaft 225 feet deep. The last notable pocket found in it was one that yielded 386 ounces of gold from 2 tons of ore mined by J. A. McMahon in 1940. J. B. Clark, 1307 Sixteenth Street, Sacramento, is the owner.

Sugarman and Nigger mine (patented) contains 27 acres in S½SW¼ sec. 19 and N½NW¼ sec. 30, T. 2 N., R. 15 E., on the west slope of Bald Mountain, about 2 miles north of Sonora. It has been one of the more important producers among the pocket mines, having been worked off and on since 1850. The earlier operations and mode of occurrence of the pockets were described by Tucker.[11]

The gold production is claimed to have been about $700,000 and much of it was beautifully crystallized, occurring in white quartz associated with petzite, sylvanite, and pyrite. The first work was by Chileans in pioneer days in the Moreles adit on the north end of the Sugarman claim. Americans began work about 1875 and drove a series of four adits on this claim, the lowest or Herold tunnel being reported as 1800 feet long, extending nearly the full length of the claim. From this adit 860 feet from the portal, a winze was sunk. The Sugarman inclined shaft connected with this winze and the various adits. The Nigger claim was first worked through an adit near the level of Portuguese Gulch, for a length of 500 feet. In 1929, the Nigger shaft was sunk 450 feet and levels were run at 250 and 380 feet by Sugarman Mines, Inc., who produced over $55,000 during 1929-30. R. M. Nelson and associates of Sonora took over in 1930 and reported production of substantial amounts for several years. In 1939, Bald Mountain Mines, Inc., was incorporated by Ralph Butler, Sonora, and J. C. Griffith and Rolland A Vandegrift of Sacramento. Production of several thousand dollars a year was reported for 1938-39.

The ''high-grade'' was crushed in a spring-pole mortar and the residue was sent to Selby smelter in these later operations. A small Huntington mill has been used at times to crush quartz that accumulated during the search for pockets, but this never amounted to more than 100 to 300 tons a year. As a rule, little water enters the workings, but in wet weather as much as 240 gallons per minute had to be handled.

Transierra Gold Mining Company, 156 Montgomery Street, San Francisco, has been engaged for some time in reopening the workings of the North Star mine in SW¼ sec. 32, T. 2 N., R. 16 E., midway between Tuolumne and Soulsbyville. W. A. Hayes is president of the company.

The North Star and adjoining Laura claim, both patented, contain 37.09 acres. These claims were held and worked jointly and had a 10-stamp mill about 60 years ago. They are on the Eureka vein which averages 5 feet in width, strikes northwest, and dips N. 50° E. The country rock is granodiorite. The Laura shaft was sunk 436 feet and North Star shaft 400 feet 35 years ago.

---

[11] Tucker, W. Burling, Tuolumne County: California Min. Bur. Rept. 15, p. 163, 1915.

The present company had reopened the North Star shaft to 400 feet late in 1947. They reopened the drifts on the 250-foot level, extended the north drift 75 feet to a length of 200 feet, and the south drift for 102 feet to a length of 252 feet. This south drift has since been extended in search of ore at anticipated intersections. Work has also been done on the 400-foot level to prepare for drifting both ways. The company reported finding ore on the 250-foot level north drift and in the shaft between the two levels.

Gold Placer Mining

The placer mining area in the limestone and pocket belts of this county, around Columbia, Shaws Flat, Springfield, Kinkaid Flat, Sonora, and vicinity, is reputed to have been the richest ever discovered. These districts are credited with a combined output of about two-thirds of the total of over $150,000,000 in gold recovered in placer mining in the county previous to 1900. Of this, $55,000,000 has been credited to Columbia and Springfield. Most of this rich, shallow surface placer ground had been worked out before 1870. There were large numbers of separate claims, ranging from 100 or 200 feet square up to 500 feet square and these were worked by groups of two to six men each. The ''pay dirt'' was hoisted out of the potholes and crevices in the limestone bedrock by whims and water wheels which raised it high enough to allow for grade for sluices.

The placers in the Columbia and Sonora districts were enriched by the erosion of the upper zones of numerous pockety quartz veins, and many large nuggets were found, ranging up to 75 pounds. A piece of gold and quartz which sold for $30,000 was found at Holden Garden. But these, large as they were, did not compare in size with the masses of pocket or ''specimen rock'', often containing more gold than quartz, found at intervals in place in the pocket mines up to the present time.

Channel mining has been quiet in the county in recent years. From 1931 to 1942 several dragline dredging outfits were in operation. As a matter of record, the results of some of these, and other surface mining operations with mechanical equipment, are briefly noted. In each case, the production figures have been previously released for publication in the Minerals Yearbook, U. S. Bureau of Mines.

Hard Gravel claim is a patented claim of 20 acres in N½NW¼ sec. 18, T. 2 N., R. 15 E., 1¼ miles east of Columbia. Raymond and Clarence Dondero are the owners. In 1937, Premier Mining Company leased the claim and used tractors, rooter, and scrapers to strip overburden and dig gravel. They mined and washed 12,000 cubic yards of gravel which yielded 293 ounces of gold.

H. Hellwig took over in March 1939 the land that had been partly worked previously by Moccasin Mines. The dragline, equipped with a 2 cubic yard bucket, handled 438,223 cubic yards on Moccasin Creek, from which 2506 ounces of gold and 431 ounces of silver was recovered, in 1939.

E. A. Kent operated dragline dredges at several places in the county including Woods Creek, from 1937-39; on Tuolumne River, and on the Mangante placer on Curtis Creek near Stent in 1938 and early 1939; on Sanguinetti Ridge near Chinese Camp in 1940, and on the Rosasco Ranch, Lyons Ranch, Six-bit Gulch near Chinese Camp, and Sanguinetti property in 1941 and 1942. The only production figures released showed recovery of 224 ounces of gold and 15 ounces of silver from 53,000 cubic yards mined on the Lyons Ranch and 308 ounces of gold and 21 ounces of silver from 52,500 cubic yards mined on the Rosasco Ranch in 1942.

Menke-Hess placer at the head of Six-bit Gulch 2 miles south of Chinese Camp was worked by Menke-Hess Gravels, Inc., in 1936-37. A power shovel was used for mining gravel which was hauled out of the pit by a gasoline locomotive, and run over a grizzly to dispose of boulders. It was then washed in a stationary plant. A total of 160,000 cubic yards yielded $92,820 but this was said to be insufficient to give the operators a profit.

Chinese Gravels, Inc., placed a dragline and floating washing plant half a mile below these workings in the gulch and worked a length of several hundred feet in 1938, but found the bedrock too hard to permit saving more than a small part of the indicated gold content, most of which was evidently on or near bedrock. Other operators worked the property in 1940-41 but no production figures were released.

Mullin & Company operated a dragline dredge on Sullivan Creek in 1940 and recovered 419 ounces of gold and 41 ounces of silver from 55,700 cubic yards of gravel.

George Mullins Company (also mentioned as Mullin-Hampton Dredging Company) mined 85,000 cubic yards of gravel on the old Dondero property 1 mile east of Columbia in the first half of 1941 and recovered 365 ounces of gold and 28 ounces of silver.

Avery Moore, Long Barn, has recently obtained title to a large number of unpatented placer mining claims in that vicinity and has recently started work also to reopen the Sledge drift mine, near Long Barn and 4 miles from Confidence by road.

The Sledge mine was worked in a small way by the Sledge family. In 1913 it was drilled by Tuolumne Deep Channel Mining Company and in 1923 a later company extended an old tunnel to a length of 600 feet. Gravel shows in the face of the old pit, near the tunnel portal. The tunnel struck rim gravel near the face. The gravel seen there was evidently from an intervolcanic channel, with very little quartz. No work was done after striking gravel. About a quarter of a mile ahead of the face of the tunnel, a shaft was started, but evidently did not reach gravel. Late in 1947, Moore began surface work to reopen the tunnel.

Punch Bowl placer mine is 6 miles west of Jamestown in N½ sec. 20, T. 1 N., R. 14 E., on Table Mountain; C. E. Shafer, Jamestown, is the owner. For the past 1½ years it has been leased to Industrial Metals, Inc., C. W. Stone, president, 705½ Washington Street, Sonora, who hold 225 acres. The land extends across the entire width of Table Mountain, the spectacular flow of latite which covered and preserved ancient auriferous gravel for several miles in this region. The land is situated where the lava covers the contact of Jurassic (Mariposa) slate and gabbro.

Although this old mine is said to have been opened as early as 1854, and has been active periodically since, not much gravel has been washed. A bedrock adit started at an elevation of 1260 feet traverses slate for 700 feet and then enters gabbro. It is said to strike gravel at 1300 feet from the portal. The present company has reopened it for 1500 feet of a total reported length of 1800 feet. Near the 1500-foot point, a raise was put up 28 feet by former operators and gravel on the supposed east rim or "Upper Table Mountain Channel" was prospected for a length of 800 feet. This work was done at intervals between 1890 and 1934. The larger pieces of gold found ranged from 1½ to 5½ pennyweights, and the gold content was reported from $1.50 (old price) to $2.50 a cubic yard.

C. W. Stone of the present company estimates the gravel in the low channel, which is believed to be unworked, may average $2.50 a cubic yard. Work has been temporarily suspended on account of unfavorable labor conditions.

About 1900, or earlier, two inclined shafts, 220 and 420 feet inclined depth, were sunk to connect with the adit. The deeper of these would need to be extended downward about 240 feet to reach the adit level 100 feet ahead of the present face. There are also two old raises from adit level to surface, at points 900 and 1000 feet respectively from the portal. The latter is 100 feet long. In the deeper parts of the channel, gravel will probably be cemented. It carries some cobbles of granite, schist, and andesite, and a little quartz.

Graphite

Graphite was found at several places in the course of early placer mining in T. 2 N., R. 14 E. Two properties were productive and some work was done on another.

Eureka Plumbago mine is a patented placer claim of 100 acres in the W½ sec. 24, T. 2 N., R. 14 E., 1½ miles north of Sonora. A. Pedro Estate et al., Columbia, are the owners. J. Ross Browne[12] gave an interesting account of the deposit and the manner of preparing the graphite for market. Work had reached a depth of 65 feet at that time and much of the graphite was found pure enough to ship as mined, but part of it had to be washed. This was done in a puddling machine like an arrastre, that had harrow teeth in place of grinding stones. The graphite flakes, being light, were drawn off through a spout at the top, and settled in reservoirs. The water after becoming clear was drawn off, and the fluid graphite mud was run into vats and sun-dried before sacking for shipment. About 500 tons had been shipped by September 1, 1867. Most of it went to Liverpool, England, where it was said to sell for $100 a ton. The vein was 20 to 40 feet wide with ''yellow sandstone'' footwall and ''soft clay slate'' hanging wall.

Morgan graphite mine is on the patented Black Hawk Plumbago placer mine, which contains 60 acres, mostly in E½ sec. 9, T. 2 N., R. 14 E., 1¼ miles west of Columbia. Some graphite is believed to have been produced and shipped from this mine about 1900, but no details are available. Ralph C. Morgan, Box 44, Fairfield, California, has been assessed for this land in recent years.

Lead

Small amounts of lead have been reported as a by-product of concentrate from gold quartz ores, especially from those in the east belt. No mines are known to have been worked for their lead content alone.

Peter Couture, c/o Pickering Lumber Company, Tuolumne presented a sample of good galena ore to the county exhibit in Sonora in December 1947. He reported he found this ''on Griswold Creek three-quarters of a mile from where Skull Creek empties into it''. This would be within a mile of the township line common to Ts. 4, 5 N., R. 16 E. The sample appears to be float.

---

[12] Mineral resources of the United States west of the Rocky Mountains (for 1867), pp. 252-253, 1868.

Limestone and Marble

The limestone beds, altered to marble, which extend from the vicinity of Murphy in Calaveras County southward through Columbia and Sonora are 2 miles wide north of Columbia. In that region they have been worked principally for marble in the past, but for several years the quarries have been closed. At present marble is being crushed in one plant for making terrazzo, and one property is supplying stone to the kilns of U. S. Lime Products Company a mile south of Sonora, where an underground mine is also producing limestone. What was undoubtedly once a continuous belt of limestone has been broken for a distance of about a mile north of Curtis Creek by a granitic intrusion and later erosion. From Curtis Creek 4 miles south of Sonora, the limestone continues southward for a mile and then turns east, extending 8 miles, into the canyon of the Middle Fork of Tuolumne River.

The limestone and marble resources of this county have been described, with numerous analyses, in a recent report of the Division of Mines[13] and will be only summarized here.

The marble near Columbia, Springfield, and Shaws Flat was uncovered by the placer miners who found rich deposits of gold in the thin layer of soil and gravel which originally mantled it. The rough surface of the limestone, full of shallow pits and solution cavities, made a good riffle for gold. Marble quarrying began near Sonora in 1860 and continued off and on until 1942. The product was of superior quality, and the district was the most important source of marble in the state. The supply of marble here is immense, and working conditions are favorable. However, marble, granite, and sandstone used for building construction require a great deal of expensive skilled labor, and none of them has been able to compete with clay products and concrete, except for interior work, where California marble has had competition from marble from other states and from foreign countries.

This marble generally contains considerable magnesium, but not sufficient to be properly called dolomite, so far as available analyses indicate. It is dense and hard, taking a fine polish and having a compressive strength of 25,000 pounds per square inch. The weight is 169 to 182 pounds per cubic foot. The principal production has been a white, fine-grained marble with blue veining, although other shades to nearly black, including a beautiful buff stone with reddish veining, called Portola marble, have been produced from the Columbia quarry.

Except for the operations of U. S. Lime Products Company 1 mile south of Sonora, there is no activity in the southern part of the limestone belt at present. In a recent report[14] the writer has shown that high-grade limestone, varying in composition from high-calcium stone with minor impurities, to nearly true dolomite, occurs there in large deposits.

Bell Columbia marble quarry, in the town of Columbia is assessed to Equipment Sales Company, 679 Bryant Street, San Francisco. Marble was produced from 1918 to 1926 and shipped in blocks weighing 6 to 14 tons to firms in Oakland and San Francisco. The stone varies from pure white to dark blue-veined, and from fine to medium coarse crystal size. The content of silica, alumina, and iron oxide is very low for a marble. It carries from 2 to 14 percent MgO. The compressive strength is from 22,000 to 24,890 pounds per square inch. This marble was used in the interiors of several large buildings in San Francisco. The quarry is 5 miles by paved highway north of the Sierra Railway station at Sonora. Electric power is available. All equipment has been removed.

---

[13] Logan, Clarence A., Limestone in California: California Jour. Mines and Geology, vol. 43, pp. 341-348, 1947.

[14] Logan, C. A., op. cit. 1947, pp. 341-348.

G. Bordoli and Brothers quarry is about 1 mile north of Sonora near the Columbia road. In the 1920's a deposit of white marble was worked here in a small way to make terrazzo.

Childress Ranch in secs. 20 and 29, T. 1 N., R. 15 E., is owned by O. D. Childress, R.F.D. 1, Sonora. It is 5 miles by road south of Sonora. The deposit may be traced for a width of 650 feet from east to west near the line between sections 20 and 29 and for a quarter of a mile in length. It is at an elevation of 1600 feet, and does not rise above the flat land around it. No work has been done.

Columbia marble quarry was for many years the most important marble quarry in the state. It was closed in 1942 and all equipment has been removed. The holdings were in secs. 2 and 3, T. 2 N., R. 14 E., and sec. 34, T. 3 N., R. 14 E. The land on which the marble-sawing plant stood and the old quarry in section 34 have been sold to U. S. Lime Products Company, 1840 East 25th Street, Los Angeles 11. They are quarrying marble at this site, 2½ miles north of Columbia and hauling it to their plant 1 mile south of Sonora to make lime. The operations of Columbia Marble Company from 1891 to 1942 have been fully described in our past reports.[15]

Dunning Ranch is assessed to Harry C. and Ariel J. Dunning, R.F.D. 1, Sonora. It is in sec. 20, T. 1 N., R. 15 E., 4½ miles south of Sonora by road. This land contains the north end of the large deposit described under Murphy, Mayhall, et al. It was undeveloped at the time of the last report.[16]

Engler Lime Company operated a lime plant at Shaws Flat a generation ago. In 1947, land assessed to August Engler in NE¼ sec. 23, T. 2 N., R. 14 E., 19.97 acres, was leased to Sonora Marble Aggregates Company.

Mayhall Ranch, assessed to William E. and Jennie Mayhall, P. O. Box 659, Sonora, covers parts of secs. 26, 27, 32, 34 and 35, T. 1 N., R. 15 E., 8 miles, more or less, from Sonora or Jamestown by good roads. The elevation ranges from 1560 to 2040 feet.

On the west property line of this ranch, where it joins the Musante land the writer cut samples across a width of 900 feet in the large deposit of limestone which extends for 1½ miles eastward across the ranch. These samples, shown below, indicated a 600-foot width of rather coarsely crystalline, firm, even-textured gray to white, high-calcium limestone on the north (sample T3) and 300 feet of finely granular "sugary" magnesian limestone, almost a dolomite in composition, on the south (sample T4). These samples were taken along the line between sections 33 and 34 and apply also to the Musante land.

---

[15] Tucker, W. Burling, Tuolumne County: California Min. Bur. Rept. 15, pp. 169-172, 1915.
Logan, C. A., Tuolumne County: California Min. Bur. Rept. 17, pp. 488-489, 1920 . . . Rept. 24, pp. 51-53, 1928.
Logan, C. A., Limestone in California: California Jour. Mines and Geology, vol. 43, pp. 343-344, 1947.

[16] Logan, C. A., op. cit. 1947, p. 344.

Analyses by Abbot A. Hanks, Inc., Nov. 13, 1943

	Sample T3	Sample T4
Insoluble	0.54%	2.28%
Ferric and aluminic oxides	0.57%	0.91%
Calcium carbonate	95.76%	60.77%
Magnesium carbonate	2.84%	35.46%

At this place, the total width of limestone is probably 2100 feet, but much of it is covered by alluvium in the valley of Blanket Creek. The deposit has not been prospected or developed.

McCormick Estate, c/o Frank A. McPherson, Sonora, owns land 2 miles south of Sonora near the center of sec. 7, T. 1 N., R. 15 E., on which limestone outcrops. Although soil conceals much of the deposit, except where it was exposed by early-day placer mining, the limestone probably extends for half a mile from north to south across this land, with a width of over 100 feet. Backs of 125 feet could be obtained from the level of Sullivan Creek near the north end. An analysis of a sample taken by the writer shows 90.79 percent $CaCO_3$, 7.36 percent $MgCO_3$, 0.91 percent insoluble, and 0.61 percent ferric and aluminic oxides.[17]

McLean limestone deposit, containing 21.54 acres in sec. 23, T. 2 N., R. 14 E., is now (May 1948) owned by Sonora Marble Aggregates Company. It is at Shaws Flat, 5 miles by paved road north of Sonora and is part of the area exposed by early placer mining. A sample taken by the writer in 1946 showed 59.22 percent $CaCO_3$, 37.19 percent $MgCO_3$, 3.21 percent insoluble and 0.30 percent ferric and aluminic oxides. It is a hard, fine-grained stone, ranging from white to gray in color.

McPherson Ranch property, assessed to Winnie McPherson, R.F.D. 1, Sonora, is in secs. 7 and 18, T. 1 N., R. 15 E. The limestone is partly covered by soil, but probably extends for almost half a mile southward across the land and near the south end is about 300 feet wide. The analysis is probably similar to that given under McCormick, which adjoins on the north. It is undeveloped. Sonora railway station is 2¾ miles north by road.

Murphy Brothers Ranch is assessed to Albert, George, and Charles Murphy, R.F.D. 1, Sonora. It contains several hundred acres in secs. 20, 21, 28 and 29, T. 1 N., R. 15 E., extending from the Sonora-Algerine road 5 miles south of Sonora to the Musante Ranch. Southward from Curtis Creek, through the Murphy land, the limestone has been eroded to the general level and is partly covered by soil. The limestone outcrops are each usually only a few square feet in area, seldom over 1 foot high, and may be as much as 20 to 40 feet apart. The land surface is too nearly flat to give drainage for a pit or quarry. No work has been done. The exposed limestone is white to light gray, firm textured, fine to medium crystalline and of good quality. A sample taken by the writer across a width of 540 feet gave the following:

Analysis by Abbot A. Hanks, November 1943

Insoluble	0.46%
Ferric and aluminic oxides	0.13%
Calcium carbonate	95.41%
Magnesium carbonate	3.93%

Musante Ranch is assessed to Giacomo Musante et al., R.F.D. 1, Sonora. This ranch of about 500 acres in secs. 28, 33, and 35, T. 1 N., R. 15 E., is traversed for about a mile by the same limestone deposit already described under Mayhall and Murphy Ranches, between which part of the Musante holdings are situated. The limestone here is 7 miles by good road from Jamestown. On the north side of the road, in the eastern part of section 33, the limestone extends to the tops of two hills, offering opportunities for opening quarries from which large tonnages could be obtained. As mentioned under Mayhall Ranch, the deposit is probably 2100 feet wide from north to south along the line between sections 33 and 34, which here is the east line of the Musante land. The samples of which analyses are shown under Mayhall, apply to the Musante land as well, covering widths of 600 feet and 300 feet respectively and indicating marked variation in the characters of the two beds. The amount of limestone available here above the road level, assuming that the deposit extends to a vertical depth of only 100 feet, would be several million tons. No work has ever been done on it.

---

[17] Logan, C. A., op. cit. 1947, pp. 345-346.

Port Stockton Cement Company, 1113 Hearst Building, San Francisco is assessed on the county tax rolls for over 700 acres of land in secs. 2, 3, T. 2 N., R. 14 E., and nearby. This land is in the large limestone belt ½ to 1 mile north and northwest of Columbia. No indication of activity has been noted on the land recently.

Sonora Marble Aggregates Company, 356 Church Street, San Francisco, operate a plant built in 1947 at Shaws Flat in sec. 23, T. 2 N., R. 14 E., about half a mile west of the Sonora-Columbia highway. It is a limited partnership with L. C. Sundberg as manager. The company owns 21 acres patented, and leases the August Engler limestone property of 19.97 acres in SW¼ NE¼ sec. 23. It also owns mining claims and leases lands in three counties from which stones of seven colors are obtained. Fifteen men are employed.

The principal products are terrazzo aggregates and aggregates for built-up roofing in place of pea gravel, but there is some sale of by-product dust, etc. The plant is in a large area of hard magnesian limestone and marble, ranging in color from white to dark gray, where Walter S. McLean formerly operated. Surface workings and hand labor supply this limestone nearby. A yellow marble is obtained near Vallecito. Green and black serpentine are also used.

The principal items of equipment for crushing, sizing, and sacking the stone are housed in a large building. Crude rock, up to 1-man size, is hauled to the plant by truck in buckets of about 36 cubic feet capacity and fed by hand to a 36-inch jaw crusher. Further crushing is done by a set of 32-inch rolls in closed circuit with a Link Belt 3- by 8-foot scalping screen, from which sand and dust are drawn off. Belt conveyors connect the crushing units on the lower floor with the scalping screen on the upper floor, and take through sizes from the scalper to a six-deck Rotex sizing screen. The five-compartment finish bin with electric stacker supplies finished products for sacking through chutes on the lower floor. Products sizes are from ½-inch to 16-mesh for pre-cast terrazzo and ⅜-inch to ⅛-inch for terrazzo laid in place. Roofing aggregate ranges from ⅛-inch to ⅜-inch. Part of the by-product finds is used in oxychloride cement. Shipments are made as far as Los Angeles.

U. S. Lime Products Corporation, 57 Post Street, San Francisco. The lime plant and lime deposit 1 mile south of Sonora in sec. 1, T. 1 N., R. 14 E., have been operated many years by this company and its predecessor, Pacific Lime & Plaster Company. Recently some changes have been made in management, and the marble property formerly belonging to Columbia Marble Company, 131 acres in sec. 34, T. 3 N., R. 14 E., 3 miles northwest of Columbia, has been purchased.

The property south of Sonora covers 4000 feet along the deposit which extends southward from Columbia through the county seat, terminating about a mile south of Sullivan Creek. This is the site of the lime plant. Limestone high in calcium and low in magnesium content is produced by underground mining, using the room and pillar system. Most of the stone is handled by Eimco-Finlay loaders, and a conveyor belt has been installed recently to deliver stone from the shaft to the crushing plant. Mining has reached a depth of 315 feet. The deposit lies between walls of Calaveras (Mississipian) rocks and is cut by several dikes. For the most part, it is solid, coarsely crystalline white and light-gray limestone with a small amount of magnesia and very little silica, alumina, and iron oxide.

The stone mined from the recently purchased land near Columbia is the magnesian marble quarried from the old pit of Columbia Marble Company. This is much higher in magnesium carbonate than the stone south of Sonora, and is commonly called dolomite. It is hauled 8 miles in trucks to the plant. All of the marble-sawing equipment once used by the former operators has been removed from this land.

Some of the 13 vertical kilns of the old plant have been used recently for burning dolomite. Little change is reported in their operation since 1928. They are lined with three courses of firebrick and have a capacity of approximately 100 tons of lime a day.

A new rotary kiln, 6 by 120 feet, has been installed for burning high-calcium lime. This is lined with Stockton firebrick 9 inches thick at the firing end and 6 inches at the cooler end. This brick is said to last $1\frac{1}{2}$ years in the hot zone. The limestone is in this kiln about 6 hours and maximum kiln temperature is 2400° to 2800° F. The kiln is fitted with a Western Precipitation Company multi-cone dust collector and the main tall stack has been sealed off. Lime production capacity is somewhat curtailed because of the tendency of the stone to decrepitate, requiring care in regulating heat and speed. Fuel oil is used.

Besides serving the steel trade with lime, the company screens three sizes of quicklime, 16-mesh, $\frac{1}{4}$-inch, and $\frac{5}{8}$-inch. The hydrate plant produces three grades of lime hydrate, the best being marketed under the trade-name of Sierra Superfine hydrate, the second as Sierra, and the third for agricultural use. A Raymond high-side roller mill is used to grind both lime and limestone. A poultry-grit plant, with elevator and shaking screens, produces turkey and chicken grits of different sizes, and chicken flour.

Magnesite

Shipments of magnesite were made from the county in 1916-17, 1926 and 1941. The deposits are in a large serpentine area southwest and southeast of Chinese Station on the Sierra Railway.

Gray Eagle magnesite deposit is in the E$\frac{1}{2}$ sec. 16, T. 1 S., R. 14 E., $2\frac{1}{2}$ miles southeast of Chinese Station. Several hundred tons of magnesite was mined from a lens striking N. 65° E. and dipping 45° NW. at the eastern contact of serpentine and porphyrite. It was worked through a crosscut adit 310 feet long and a drift along the magnesite at a depth of 98 feet, as well as from an upper drift 34 feet higher, run from the bottom of a shaft 64 feet deep. The magnesite was up to 10 feet wide and of good grade. A calcining plant was built at Chinese Station in 1923 but little ore was treated. The last production was in 1941.

Maki magnesite claims were in S½ S½ sec. 6, T. 1 S., R. 14 E., less than a mile south of west from Chinese Station. Some ore was mined but so far as known, no shipments were made.

Monarch prospect was in the same locality, 1½ miles from Chinese Camp.

White Rock magnesite mine is in the SW¼ sec. 6, T. 1 S., R. 14 E., 1¼ miles south of west from Chinese Station. The vein, which was 1 to 2 feet wide, was worked by surface cuts and by a shaft 60 feet deep. It strikes nearly east and dips steeply south. Three carloads of magnesite were shipped from it in 1917.

Molybdenum

The occurrence of small quantities of molybedenite in quartz veins having walls of granite or granodiorite has been noted at many places in the Sierra Nevada region. In Tuolumne County, H. W. Turner[18] mentioned such showings about 3 miles north of west from Tower Peak, and in a quartz vein on the south side of Knight Creek, northeast of Columbia. The latter can be more definitely placed as a vein which has been worked for gold at times since 1900, in the Contention mine, near the north corner common to sections 16 and 17, T. 3 N., R. 15 E. This was erroneously mentioned in the Big Trees folio of U. S. Geological Survey as north of Knight Creek.

In 1936, R. N. Kappel of Kappel Mining Company, then operating the Contention mine, made some tests with the idea of saving the molybdenite, but the company lapsed in 1937 and there is no record of molybdenite production.

Slate

A belt of Mariposa (Jurassic) black clay-slate strikes northwest across the west side of the county. A quarry was operated on this slate near Hetch Hetchy Junction (also known as Rosasco) from 1931 to 1940. It is in sec. 36, T. 1 S., R. 13 E. within 200 feet of the tracks of the Sierra Railroad. A crew of five men produced at the rate of about 500 tons a month for part of the above period. The slate was shipped to San Francisco by Walter S. McLean. It was crushed to make roofing granules for ''ready roofing'' and dust was said to be utilized as filler in a coarse grade of paper used for lining refrigerator cars.

In 1941, Walter C. Sundberg, Sonora, sold some slate for flagging.

Soapstone and Talc

Soapstone and talc have been found at several places in the county but the only sales reported were of soapstone in 1931-32, from near Jamestown. It was used locally in earlier days for chimneys and buildings. Talc outcrops have been reported at Shaws Flat, on Yankee Hill, and near Shawmut. Soapstone has been noted in the Moccasin district 2 miles from the Hetch Hetchy Railroad, near Crimea House 2 miles east of the Sierra Railroad, and probably at several other points, as in past years several persons have listed deposits or tonnage for sale without stating the location. Outcrops of serpentine are numerous, as mentioned under chromite, and soapstone may be expected in this serpentine. In the region of the dolomitic limestone, however, there is a possibility of talc occurring although no description of such a deposit has been noted for Tuolumne County.

---

[18] Turner, H. W. Notes on rocks and minerals of California: Am. Jour. Sci. (4th ser.), vol. 5, pp. 426-427, 1898.

Stone Industry

Beerman & Jones, Sonora, have been listed for many years as producers of crushed rock at Soulsbyville. Use has also been made at times of waste marble from the Columbia district for road work.

Two small "granite" quarries were operated 25 years or more ago. The stone they produced is a granodiorite of medium texture and pleasing bluish gray color.

Phoenix Lake Granite Company's quarry was in sec. 23, T. 2 N., R. 15 E., M. D., 6 miles northeast of Sonora.

Sonora Granite Company shipped a few carloads of the "granite" from the Rablen Ranch in sec. 14, T. 1 N., R. 15 E., M. D., 3 miles from the Sierra Railway.

Tungsten

In common with other counties along the western slope of the Sierra Nevada, Tuolumne has a few prospects of scheelite. Most of them were described by J. M. Little.[19] Nine prospects mentioned by him are in a zone 1000 feet wide by 4000 feet long. Six described as "interruptions in quartz veins" were found in place and three were boulders of tactite "float." They are on the west slope of Mount Lewis, 1¾ miles southeast of Confidence. Not enough work had been done on any of them to determine their size at the time of his report, and none had made any commercial production.

Anita No. 1 scheelite claim is in SW¼ SW¼ sec. 34, T. 1 S., R. 19 E. Peter Molander, Groveland is the owner. The claim is at an elevation of 4800 feet on the side of Crocker Ridge 26 miles east of Groveland. It was visited with the owner in May 1948. An open cut 10 feet deep by 20 feet wide had been run southeast about 20 feet, revealing a contact of granodiorite and limestone. Overburden had sloughed off and covered the bottom of the face. Samples were taken across the exposed upper face of the cut but these failed fluoresce under the ultraviolet lamp. Good fluorescence was obtained with samples on the dump which the owner states came from a layer in the bottom which at the time was covered with waste. Not enough work had been done to give an idea of the size of the deposit. The scheelite is associated with quartz having a greasy luster, and much garnet is present. No production has been made.

Dorothy Lake prospect is in secs. 19, 30, T. 4 N., R. 22 E., in the high mountains near the Sierra Nevada summit in Yosemite National Park.[20] No production has been reported.

Mackey Ranch is in secs. 21 and 28, T. 1 N., R. 14 E., 2½ miles southwest of Jamestown. Professor Arthur S. Eakle reported "a small amount" of scheelite on this ranch.[21] No commercial production of scheelite is recorded, although the ranch has produced some copper, chromite, gold and silver.

Tuolumne tungsten mine, near Twain Harte, reported some scheelite production in 1942.

---

[19] Little, J. M., Tungsten deposits of the Confidence mining district, Tuolumne County: California Div. Mines Rept. 38, pp. 283-289, 1942.

[20] Tucker, W. Burling, and Sampson, Reid J., Mono County: California Div. Mines Rept. 37, p. 581, 1941.

[21] Eakle, Arthur S., Minerals of California: California Min. Bur. Bull. 91, p. 257, 1923.

BIBLIOGRAPHY

Bradley, Walter W., Mineral production (California) for 1915-18: California Min. Bur. Bulls. 71, 74, 83, 86.

Bradley, Walter W., Magnesite in California: California Min. Bur. Bull. 79, pp. 138-140, 1925.

Browne, J. Ross, Mineral resources of the states and territories west of the Rocky Mountains (for 1867), p. 224, 1868.

Cater, Fred W. Jr., Chromite deposits of Tuolumne and Mariposa Counties, California: California Div. Mines Bull. 134, pt. 3, pp. 3-14, 1948.

Eakle, Arthur S., Minerals of California: California Min. Bur. Bull. 91, p. 257, 1923.

Julihn, C. E., and Moon, Lowell B., Summary of Bureau of Mines exploration projects on deposits of raw material resources for steel production: U. S. Bur. Mines Rept. Inv. 3801, 33 pp., 1945.

Little, James M., Tungsten deposits of the Confidence mining district, Tuolumne County: California Div. Mines Rept. 38, pp. 283-290, 1942.

Logan, Clarence A., Sacramento field division—Tuolumne County: California Min. Bur. Rept. 24, pp. 3-53, 1928.

Logan, Clarence A., Mother Lode gold belt of California: California Div. Mines Bull. 108, pp. 153-179, 1934.

Logan, Clarence A., Limestone in California: California Jour. Mines and Geology, vol. 43, pp. 341-348, 1947.

Tucker, W. Burling, Tuolumne County: California Min. Bur. Rept. 15, pp. 132-172, 1915.

Tucker, W. Burling, and Sampson, Reid J., Mono County: California Div. Mines Rept. 37, p. 581, 1941.

Turner, H. W., Notes on rocks and minerals of California: Am. Jour. Sci., 4th ser., vol. 5, pp. 426-427, 1898.

BARIUM

By W. B. Winston *

OUTLINE OF REPORT

Page
Properties of the metal 85
Barium compounds 85
Barium ores 87
Tests for barium 87
Mode of occurrence 88
Location of deposits 88
Prospecting and mining methods 90
Preparation of barite for market 91
Preparation of barium compounds 92
Marketing barite in the United States 93
Uses 94
History 95
Bibliography 96

PROPERTIES OF THE METAL

Barium (Ba) is a metallic element of the alkaline earth group and resembles calcium chemically. The metal was probably not obtained in a pure state until recent years when won by new methods of electrochemical deposition. Barium is difficult to keep in the metallic state because it oxidizes so easily. When freshly cut, the pure metal is a silvery grayish white (like lead) and is lustrous, ductile, and malleable. Some authors have erroneously described the metal as being yellow or golden yellow in color. In air barium oxidizes rapidly and soon burns. In the oxyhydrogen flame it burns with a yellowish-green color. Barium decomposes water slowly, at ordinary temperatures, with evolution of hydrogen and formation of the relatively insoluble hydroxide ($Ba(OH)_2$). The latter is strongly alkaline, and for this reason barium is often spoken of as an alkaline earth metal. Sulfuric acid reacts with barium liberating hydrogen and forming the insoluble sulphate. The atomic number of barium is 56; the atomic weight is 137.37; the valence is 2; and the specific gravity is 3.5. The metal is soft and can be cut with a knife. It melts at red heat at a temperature above that of cast iron, but cannot be distilled. Barium has one isotope.

BARIUM COMPOUNDS

Barium salts generally are colorless crystals or white powders. Most of them are insoluble in water. Those soluble in water are: halogen compounds, nitrides, nitrates, chlorates, and acetates. Barium-halogen compounds are volatile and impart a yellowish-green color to the Bunsen flame. Other barium salts produce the same color in a Bunsen flame, but not so prominently. Barium carbonate is decomposed by heat into carbon dioxide and barium oxide. Barium also forms a dioxide (BaO_2). Both oxides are insoluble in water. Many barium salts are extremely poisonous and have been known to cause a condition known as "loco" in cattle and in man.

The most important barium compounds are lithopone (a mixture of zinc sulfide and barium sulfate); blanc fixe (artificially precipitated barium sulfate); and the carbonate, chloride, nitrate, monoxide, hydrox-

---

* Junior Mining Engineer, California State Division of Mines. Manuscript submitted for publication February 1948.

ide, dioxide, sulfide, chromate, and chlorate. Lithopone is a white powder consisting of 70 percent barium sulfate and 30 percent zinc sulfide and oxide (the oxide being less than 3 percent). It is sold under various trade names such as Phonolith, Zinolith, Marbon White, and Beckton White. Blanc fixe is chemically precipitated barium sulfate ($BaSO_4$). It is a heavy, white, amorphous, insoluble powder which has identical chemical properties to those of ground barite but differs in physical properties. It is far superior to ground barite for use in pigments because of its greater whiteness, fineness, and ability to absorb oil. Blanc fixe is also known in the trade as synthetic or artificial barytes, permanent white, mineral white, new white, snow-white, constant white, baryta white, barytes white, heavy white, basofor, crested barytes, cockscomb, fixed white, and artificial heavy spar. Chemically precipitated barium carbonate ($BaCO_3$) has similar advantages over ground witherite, which is the natural mineral.

Barium chloride ($BaCl_2.H_2O$) is a white, fairly soluble salt obtained and marketed as a white powder or as flat monoclinic crystals. It has a specific gravity of 3; is stable in air; has a bitter, saline taste; and when heated loses its water of crystallization without melting.

Barium nitrate ($Ba(NO_3)_2$), also called nitrobarite and baryta saltpeter, comes in colorless, transparent, lustrous, regular octahedrons or as a white powder. It is somewhat hygroscopic (absorbs and retains water); is soluble in water; has a specific gravity of 3.2; and decomposes when heated.

Barium monoxide (BaO), also known as barium oxide, baryta, and calcined baryta, comes as a white or yellowish-white powder, or occasionally as colorless cubic crystals. It is also marketed as grayish-white, porous, amorphous lumps. The specific gravity of the crystalline oxide is 5.7. Barium oxide will react with oxygen to form the dioxide. This will break down to the monoxide at higher temperatures and finally melts at white heat. Barium oxide absorbs water and carbon dioxide upon exposure to air. It is soluble in water with evolution of heat, forming an alkaline solution of $Ba(OH)_2$. In dilute nitric or hydrochloric acid, it reacts readily to form the corresponding salts.

Barium dioxide (also known as the binoxide or peroxide) is a coarse, heavy, grayish-white amorphous powder. It melts at red heat, liberating oxygen, and is capable of absorbing carbon dioxide and water with resultant alteration to barium carbonate. Barium dioxide is insoluble in cold water but is decomposed by boiling water. It dissolves in dilute acids, forming hydrogen peroxide (H_2O_2). The specific gravity is 4.9.

Barium chromate, also known as lemon chrome, lemon yellow, pale lemon yellow, ultramarine yellow, yellow chrome, and permanent yellow, is a yellow chemical coming either in powder form or in small rhombic crystals. It is insoluble in water and has a specific gravity of 4.5.

The chlorate of barium ($Ba(ClO_3)_2.H_2O$) comes in colorless monoclinic plates or prisms or as a white powder. It is soluble in cold water and more so in hot water. The specific gravity is 3.2.

Barium is never found in the native state but is common in sulphate form (barite) and fairly common as the carbonate (witherite). These two minerals form the only barium ores produced commercially.

BARIUM ORES

Barite ($BaSO_4$) is the principal ore of barium. In commerce it is or has been known as baryta, barytes, and heavy spar, as well as barite. In Missouri, the crude ore is called ''tiff'' and elsewhere, locally, ''cawk.'' Barite, when pure, contains 65.7 percent of barium oxide and 34.3 percent of sulfur trioxide (SO_3). Ordinarily it is a heavy, whitish, translucent, crystalline mineral, but it may be almost any color and transparent to opaque. The crystallinity is not always apparent, and granular or fibrous ore bodies are common. When present in veins or other cavity fillings, much of it occurs in euhedral, tabular, or prismatic crystals. Earthy deposits of barite have been described but are not common. Crude barite is classified in the trade as ''hard'' and ''soft'' depending upon the crushability of the ore. The soft, milky, friable varieties are preferred to the hard, crystalline, vitreous varieties for most purposes. General characteristics of barite ore are: specific gravity 4.3; hardness 2.5 to 3.5; crystallinity orthorhombic, twinned crystals common; fracture, uneven; streak, white; luster, pearly to vitreous; tenacity, brittle. Barite is distinguished from calcite by its greater weight, and from both calcite and witherite by its non-effervescence in acids. Much of the crude barite mined contains impurities, notably calcium sulfate and carbonate, silica, alumina, calcium fluoride, and strontium sulfate. Mineral associates vary with the deposit. Many vein and replacement deposits contain metallic sulfides such as galena, sphalerite, chalcopyrite, and pyrite. Quartz, calcite, and fluorite may also be abundant. Residual deposits may carry considerable clay, manganese oxides, and iron oxides as well as quartz. Much of the barite mined has iron oxide coatings on lumps and crystals and in cracks and cleavage planes in crystals. Ground natural barite is known in the trade by various names such as natural barium, heavy spar, terra ponderosa, baryta white, and barytes white. Barite is the only important source of barium products, although barite and witherite are marketed together for some purposes, from El Portal, California.

Witherite ($BaCO_3$) is sometimes called ''heavy spar'' but more often simply barium carbonate. It contains 77.7 percent barium oxide and 22.3 percent carbon dioxide. Witherite crystallizes in the orthorhombic system, and crystals are nearly always repeated twins resembling hexagonal pyramids. These twinnings or ''trillings,'' as they are sometimes called, have the twinning plane parallel to the unit prism. The mineral is also found in columnar, compact, botryoidal, reniform, granular, globular, lamellar, or radial fibrous masses. Witherite may be colorless, white, yellowish, or grayish in color. The luster is vitreous to greasy; light transmission, subtransparent to opaque; streak, white; cleavage, prismatic (imperfect); hardness, 3-3.75; specific gravity 4.27-4.35; and the fracture is uneven and brittle. Witherite is much less common than barite. The usual mode of occurrence is in veins associated with galena.

Celestite ($SrSO_4$) closely resembles barite in general characteristics. Like barite it is insoluble in most acids, has similar hardness, but has a lower specific gravity (3.9). Canadian celestite has been used as a substitute for barite in paint and is considered suitable as a filler for rubber. Principal known deposits are in Canada, Sicily, and Great Britain.

TESTS FOR BARIUM

Most barium minerals when moistened with hydrochloric acid impart a yellowish-green color to the blowpipe flame. As boron and some varieties of phosphorus have similar flame colors, this test must be used with others for positive determination of the presence of barium. After strong ignition, barium minerals give strong alkaline reaction to moistened turmeric paper. Presence of barium in solutions (prepared by ignition of the mineral followed by digestion in dilute acids other than sulfuric) can be determined by addition of a few drops of sulfuric acid. An insoluble white precipitate immediately forms. This method can be used to confirm tests by flame color as noted above.

MODE OF OCCURRENCE

The element barium is contained, in small amounts, in many igneous minerals notably in orthoclase feldspar and some micas. It ranks tenth in abundance among the constituents of igneous rocks. Many spring and mine waters carry barium in chloride and carbonate form, and much travertine resulting from evaporation of such waters contains barium. Barite is found in a wide variety of rock types of igneous, sedimentary, or metamorphic origin, usually as a secondary implacement from aqueous solutions. It is not known to occur as an original constituent of igneous rocks and is usually not a product of dynamic or contact metamorphism. Barium sulfate is present in appreciable amounts in many limestones and collects with clay and iron oxide in the residual mantle as the limestone weathers away. Deposits formed from the Cambrian and Ordovician dolomites of the eastern states are typical of this type of deposit. As a gangue mineral, barite is common in ore veins formed at shallow or intermediate depths but is rare in veins formed at great depth. Commercial deposits of witherite are limited to northwestern England, Germany, and El Portal, California.

Commercially important deposits of barite, throughout the world, are of three general types: bedded deposits originally of marine origin; residual deposits (as mentioned above); and veins or vein-like masses of magmatic or meteoric origin. Barite in bedded deposits probably does not occur as an original mineral but is of secondary replacement nature. The barite gangue of metalliferous veins is usually of small commercial importance because of difficulty in profitably separating a barite product of standard commercial grade from associated impurities. Replacement bodies and cavity fillings in sandstones, shales, limestones, or other rocks are important as commercial sources, as are the residual accumulations. The majority of producing deposits occur in limestone or dolomite, although in the United States, very important workings occur in Cambrian and Ordovician residual clays. Considerable difference of opinion exists among authorities regarding the source of the barium-bearing solutions responsible for certain bedded and miscellaneous barite deposits. Some hold that the source is descending meteoric water but others postulate an ascending magmatic type of water as a parent source. In either case, the primary source of the barium probably was in minerals of crystalline igneous rocks, and the concentrations were the result of replacement of original materials by barite or precipitation of it in cavities.

LOCATION OF DEPOSITS

Barite deposits are mined on a commercial scale in many foreign countries. Those engaging in world trade are Germany, Italy, Canada, United Kingdom, Russia, and Spain. Germany produces barite from seven provinces. Italy's most important districts lie in four provinces.

Canada's principal deposits are in Nova Scotia, production from Ontario is smaller. Great Britain, which has been the chief producer of witherite, also markets barite produced in dominions, colonies, and other countries. She also markets some Scottish barite. In Russia, barite deposits of commercial grade are known in western Siberia, Georgia, and Azerbaidzhan. Recent finds have been made in Siberia, Karelia, and the North Caucasus. Germany has been the major foreign source.

In the United States, commercial production comes from three general localities—middle west, south, and west. Middle-western production comes chiefly from southern Missouri, and small production, from time to time, from Colorado (near Canyon City and Boulder). Southern deposits lie in Georgia, Tennessee, South Carolina, Virginia, and Kentucky. One of the most important districts is in the vicinity of Cartersville, Georgia. The Sweetwater district is foremost in Tennessee. In South Carolina, barite has come from placers in the Kings Mountain district which extend into North Carolina near Hot Springs. Barite is distributed through nineteen counties in Virginia. Few Virginia deposits have been worked, with the exception of those in Campbell County in the south-central part of the state. Kentucky production has never been large but many vein deposits occur in the central part of the state. Barite has also been produced in Alabama. Southern barite is almost all of residual type resulting from weathering of limestones, dolomites, and similar sedimentary rocks.

Western production is chiefly from California and Nevada; recently there has been minor production from Arizona. Vein deposits predominate in the western states. In Nevada a small production has come, at intervals, from Esmeralda and Mineral Counties. In California, barite is a common gangue mineral in vein deposits, particularly those of the silver-lead districts. Barite deposits in metalliferous veins are known in Inyo, Los Angeles, Mariposa, Monterey, Nevada, Plumas, San Bernardino, Santa Barbara, and Tulare Counties. Barite occurs in metalliferous veins in Alpine, Calaveras, El Dorado, Mono, Riverside, Siskiyou, and Trinity Counties, and with cinnabar in Orange, Napa, and Santa Clara Counties. Nodules and large concretions of dark-gray, impure barite occur in Fresno County. White barite has been described from Humboldt, Lake, Placer, and San Benito Counties. Rosettes of sand barite crystals are found in limy sandstone in San Luis Obispo County. Well-crystallized, reticulated masses of barite are common on the sea cliffs of the Palos Verdes Hills, Los Angeles County. Occurrence locations have also been reported from San Diego County and Fort Point, San Francisco.

The deposits at El Portal in Mariposa County have yielded the largest commercial production of barite in California. These were the first and, for many years, the only barite-producing deposits in the state. They also have the distinction of producing the only commercial witherite mined in the United States. This group of barite-witherite veins has been described by Fitch,[1] who states that these veins "have arisen by replacement of a bed of limestone constituting part of an isoclinally folded series of Paleozoic sediments. All gradations are found in these limestone bands, from pure barite or witherite to coarse radite-hedenbergite and other calc-silicate rocks as the margin of the granite boss is approached."

---

[1] Fitch, A. A., Barite and witherite from El Portal, Mariposa County, California: Am. Mineralogist, vol. 16, no. 10, pp. 461-468, October 1931.

In Nevada County, a large deposit of white barite occurs 5 miles north of Alta, and another deposit occurs at the Democrat barytes mine located 7 miles from Dutch Flat. The latter deposit was first worked in 1919 when commercial-grade ore tested up to 98 percent barium sulphate. Barite from this locality is all more or less off-color, ranging from pink or gray to black. This is due mainly to carbonaceous matter. Round concretions of barite were reported from the Buckeye Hill mine. White veins of barite have been described from Graniteville, and a large deposit occurs 5 miles northwest of Washington.

In Plumas County, barite is associated with lead and copper minerals in Indian Valley. Here, small veins occur in altered andesite in the Indian Valley silver mine. Large lenses of barite occur in slate about 5 miles from Almanor Siding.

In Inyo County, massive barite is found near Independence. At the Defiance mine it occurs with native sulfur. Other barite localities in this county are: Bishop Creek, White Mountains; Alabama Hills; and Shoshone.

Several notable occurrences of barite are found in Los Angeles County. Gangue barite was found at the Kelsey mine in San Gabriel Canyon, and it is also the principal gangue mineral at the Renton quarry and Black Jack mine on Santa Catalina Island. Deposits of white vein barite occur on the west side of San Dimas Canyon 8 miles northwest of the town of San Dimas; also in the Palos Verdes Hills, as previously noted.

In Monterey County, a considerable tonnage of barite was shipped from a number of lenses on the north slope of Gabilan Peak (Fremont Peak) near the San Benito County line. These lenses were associated with silicified limestone and with dolomite. No shipments have been made from there since the first World War.

Barite is a common gangue mineral in the Calico and Barstow districts of San Bernardino County. Yellow and white platy masses are found at the Imperial mine. Other occurrences in San Bernardino County, near Trona, Randsburg, and Ludlow, have been described.

In Shasta County, barite is a gangue mineral in ores of the Bully Hill mine. Large deposits of it are found north of Baird (white, massive); near Copper City; and near Castella. A small deposit is on Beegum Creek 41 miles from Red Bluff.

Massive white barite has been described from a locality near Santa Maria in Santa Barbara County. Considerable barite was taken from workings on the North Fork of La Brea Creek 20 miles from Sisquoc in the same county. A wide vein of the mineral occurring in sandstone has been reported to be situated on a ridge above the Sisquoc locality.

Barite is found at the Paso baryta mine 15 miles east of Exeter near the crest of the Sierra Nevada, and on the upper Kern River near Rattlesnake Creek, both in Tulare County.

The 1945 barite production in California came from three properties, one each in Mariposa, Nevada, and Plumas Counties. They produced the largest output for one year so far reported in this state. The 1944-45 output amounted to nearly 68,000 short tons which sold for $410,000 f.o.b. rail shipping points.

PROSPECTING AND MINING METHODS

Prospecting for barite is neither complicated nor costly. In residual deposits, where clays may effectively conceal workable ore, prospecting can be done by rodding or by sinking test pits. In the former method, a narrow, pointed steel rod is driven into the ground as far as possible and then withdrawn. Barite adheres to the rod whereas other white rocks usually leave no coating. This method is employed in Missouri where the choice of locations is based largely on the topography. Test pits are often sunk following a successful ''rodding.'' In Georgia, most test pits are circular and of sufficient width for one man to work using a short-handled pick and similar size shovel. Georgia barite ground usually requires little cribbing, and untimbered shafts 30 feet or more deep are common.

Vein deposits are not so easily prospected, particularly where overburden has concealed the outcrops. Trenching, shafting, and tunneling methods have been employed depending upon the topography. Diamond drilling and other more elaborate prospecting methods have not yet been applied to barite prospects.

Three methods of mining barite have been employed in the United States. These are: hand surface mining, as in Missouri; mechanical surface mining, as in Georgia and Tennessee; and underground mining, as in California. The tools of the hand miners or ''tiff diggers'' in Missouri consist of a pick, shovel, sledge, chisel-edged hammer, hand windless, rope, ore bucket, and axe. Uncribbed shafts are usually not over 5 feet wide. These may be sunk to a depth of over 30 feet but generally are limited to 10 or 15 feet so that excavated material can be thrown out with a shovel. Good runs of ore are followed horizontally from the bottom of the shaft to safe limits. Then adjacent pits are sunk and worked similarly. Excavated material is worked over by hand, and lumps of barite are cleaned of clay with chisel-headed hammers. Hand mining of this kind is best suited to areas where the ore comes in large lumps and bedrock is too uneven to allow working by power shovel. Hillside deposits are often mined by level-floor, open-pit methods. The face is picked or barred down and large boulders are mined around. Excavated material is sorted on the floor of the open cut and barite and clay removed separately.

In Missouri power-shovel mining, the shovel takes the full depth of the deposit with no previous stripping of overburden. The power shovel loads directly into side-dump cars and these are hauled to washing plants by gasoline locomotives. Georgia mining is all done by open-cut, power-shovel methods of similar nature, but there slopes are steeper and the overburden is often thick enough to require stripping. Adjacent deposits are sometimes connected with narrow stringers of pay ore so that the shovel can work to advantage by following along these from one deposit to the next.

Vein barite may be worked by open cuts but more often is exploited by underground methods. This depends upon the topography, wall rock, thickness of the vein, and dip of the vein as well as the kind and amount of associated minerals. In this country, no barite workings have been deeper than 350 feet.

PREPARATION OF BARITE FOR MARKET

Commercial barite is marketed as: crude barite, or barite washed free of clay and picked or jigged to remove adhering impurities; ground barite, obtained by grinding and purifying crude ore; and barium chemicals made from crude or ground barite. In preparation of crude barite for market, certain requirements must be met. The barium sulfate content must be over 95 percent and, for most purposes, ferric oxide must be less than one percent. For material exceeding one percent, a penalty is usually imposed, and a premium is often paid when the content is less than one percent. Sometimes, premiums are specified for barium sulfate content in excess of 95 percent. For use in the glass trade, barite should contain not less than 96 percent barium sulfate and not more than one-tenth of one percent (0.1) of ferric oxide. In past years, the glass trade required a crushed barite passing the 16-mesh screen with not more than 5 percent passing the 100-mesh screen. More recently, glass manufacturers have been accepting finely ground barite. Equipment necessary for thorough washing and separation of foreign materials such as hematite, manganese, and fluorite is installed near the mines. The equipment varies with the character of the ore and the scale of mining. In large plants, crude ore is dumped into logwashers (sometimes after preliminary crushing); the head discharge is screened; and hand picking of oversize and jigging of undersize material follows. Particles too fine to remain in the jig may occasionally be classified but usually are discarded.

Flotation with soap or cationic reagents can be satisfactorily applied to barite ores. Most barite is bleached before being finely ground. This is done by dilute sulfuric acid in lead-lined tanks. Sodium chloride and other chemical reagents are sometimes added. Barite mills should be so located as to permit access from numerous and changing sources of supply, as barite deposits are usually small and irregular. Very little labor is required during milling of barite. The ore is conveyed mechanically or pumped around in water, and grinding and packing are mostly mechanical functions requiring a minimum of personnel.

PREPARATION OF BARIUM COMPOUNDS

For manufacture of barium chemicals, the soft varieties of barite are preferred, but the crystalline varieties less suitable for use as ground barite can also be used. The crude barite is crushed to pea size and then mixed with pulverized coal in proportion of one part coal to four of barite, by weight. The mixture is roasted for about 4 hours in a rotary reduction furnace, and the barium sulfate is thus reduced to barium sulfide or ''black ash.'' The ''black ash,'' which is about 70 percent barium sulfide, is treated with hot water and the solution thus obtained is the base from which most barium chemicals are made. When, in the manufacture of barium chemicals, a sodium salt is added to a solution of barium sulfide, sodium sulfide is produced. This is a valuable by-product in the barium chemical industry.

In the manufacture of lithopone, barium sulfate is precipitated from the barium sulfide solution by use of a zinc sulfate solution. The zinc sulfate solution is prepared from zinc ash or skimmings dissolved in dilute sulfuric acid and must be purified before it can be used in manufacture of lithopone. This is one of the most important steps in the manufacturing process. Potassium chlorate is the agent most usually employed to purify the zinc sulfate solution. Lithopone is the white powder resulting from the simultaneous precipitation of zinc sulfide and barium sulfate when hot barium sulfide solution is added to the purified zinc sulfate solution. The precipitate is dried and calcined at about 500° C. in a muffle furnace. The hot, calcined material is then quenched in water; ground to a pulp; washed to eliminate soluble impurities; filtered; dried; passed through a disintegrator (in some cases air floated); and then packed in bags or barrels for shipment.

Blanc fixe is usually precipitated from a solution of barium sulfide by means of salt cake (sodium sulfate). It used to be made from barium chloride and salt cake or sulfuric acid. Barium sulfide yields a denser product than barium chloride and, in this process, sodium sulfide is obtained as a valuable by-product. Blanc fixe is also a by-product in the manufacture of hydrogen peroxide from barium peroxide by treatment with sulfuric acid. Blanc fixe, for use as a base in manufacture of brilliant coloring compounds, is obtained from hot concentrated solutions as a crystalline product rather than a powder. Blanc fixe is the best grade of pure barium sulfate for paint pigments, excelling the best ground barite in whiteness, fineness, and oil absorbtion. It is marketed in powder form or as a pulp containing 30 percent water.

Barium carbonate is obtained as a white precipitate from barium sulfide solutions by the use of soda ash as a precipitant. Sodium sulfide is a by-product. It can also be produced by passage of carbon-dioxide gas through a barium sulfide solution.

In this country, barium chloride is usually made by roasting crude barite with coal and calcium chloride. It may also be produced by treating witherite with hydrochloric acid and by adding calcium chloride or hydrochloric acid to a barium sulfide solution.

Barium nitrate is prepared by adding sodium nitrate (Chile saltpeter) to a solution of either barium chloride or barium sulfide. It may also be made by dissolving witherite ($BaCO_3$), barium oxide, or barium hydroxide in nitric acid.

Barium dioxide (peroxide) is prepared either from barium nitrate or barium carbonate by calcination. Barium monoxide is first formed and this is converted into the dioxide by heating at 700° C. in a current of oxygen or air. Barium chromate is made by treating various soluble barium salts with sodium or potassium chromate. Barium chlorate is formed by electrolysis of barium chloride.

The great affinity of barium for halogens, oxygen, nitrogen, hydrogen, and sulfur has made reduction of the metal an expensive and difficult process. In the light of experience gained in the production of magnesium by reducing dolomite with ferrosilicon, metallic barium can, according to Kroll,[2] be produced for less than 45 cents per pound. In his paper he reviews processes and their modifications and gives an extensive bibliography of the literature on barium metal.

MARKETING BARITE IN THE UNITED STATES

Marketing areas for crude barite or barium concentrates in the United States can be divided into three principal regions. These are the Atlantic coast, extending from Baltimore to New York and from the coast west to Ohio and West Virginia; the middle west, in the vicinity of St. Louis and Chicago; and the Pacific coast, principally in California.

Crude barite is often not consumed in the states in which it is produced. California and Missouri are exceptions. The barite of Tennessee and Georgia is shipped to grinding and paint plants along the Atlantic seaboard and as far west as Illinois. Missouri barite goes to St. Louis, to other plants in the central states, and as far east as Pennsylvania. Most of the California production is processed at Modesto, Daggett, and Oakland. Some of the largest processors own their own mines; hence little barite is on the competitive market. Most crude barite is sold on the basis of contracts for definite tonnages to be shipped over a specified period of time. United States production is limited only by the demand, as such states as California, Nevada, Georgia, Tennessee, and South Carolina have large undeveloped reserves. Barite has always been a low-priced product because of ease of distribution; ease of mining and concentration; competition with other low-priced minerals; and the fact that it is not indispensable except for a few minor uses. Cost of transportation to marketing centers governs prices to a great extent. The price of crude barite has fluctuated over a considerable range during the period from 1904 to 1946. According to U. S. Geological Survey and U. S. Bureau of Mines figures, the price of crude barite (f.o.b. mines) in 1904 was about $2.50 per ton. In 1915, it was $3.50; in 1920, $9.50; in 1930, $6.50; and in 1946, $8.50 to $9.00.

---

[2] Kroll, W. J., Processes for making barium and its alloys: U. S. Bur. Mines Inf. Circ. 7327, 16 pp., 1945.

USES

Barite, ground to different degrees of fineness, is used principally as a filler. It is well suited for addition to paper, rubber, oilcloth, linoleum, plastics, and resins. Fifty to seventy percent of all ground barite produced and sold in this country is consumed by the paper and rubber industries. Off-color barite can be used where a brown filler is permissible, as in linoleum, phonograph records, rope finishes, heavy paper, asbestos brake linings, and soft rubber goods. Barite is also used to weight textiles and leather, and in ''Bristol board,'' playing cards, and artificial ivory.

Ground bleached barite, known in the trade as ''prime white'' or ''floated barite,'' is used chiefly as a pigment or extender in white paint. Research has shown it to possess properties which make it of decided value as a paint pigment. Where a superior grade of white pigment is required, precipitated barium sulphate or blanc fixe is substituted for ground bleached barite. Lithopone is better than either of the above barium materials for use in paint and is much more widely used. It is well adapted to use in flat and enamel interior wall paints, but not so well suited to use in exterior paints because if mixed with white lead, the sulphur tends to form black lead sulphide. However, some lithopone paints for exterior use have been put on the market and are reported to be giving favorable results.

Granular barite is used extensively in the manufacture of glass. Small amounts added to the mix improve it for use in moulded forms of glass. Barite is also used in glass manufacture to flux surface froth. As a flux in brass melts, barite acts as a scavenger and is used, to some extent, for this purpose.

Finely ground barite has attained wide usage as a heavy constituent in oil-well drilling muds. ''Baroid'' type muds are used in drilling deep wells where high gas pressures are likely to exist. Up to 95 pounds of barite may be added to each cubic foot of drilling fluid. Barite-witherite ore from El Portal is ground, for this purpose, without separation. Yearly output of barite for this purpose has exceeded 150,000 short tons.

Barium chemicals have many miscellaneous uses. Blanc fixe is a constituent of lithographic inks and a base for lake dyes. As ''chemically pure barium sulphate,'' it is used as an indicator in X-ray photography. Barium carbonate is used principally in the ceramic industry for preventing efflorescence on clay wares such as brick and tile. It is also used in pottery glazes, optical glass, paint pigments, ironware enamel, and as a carbon carrier in the case hardening of steel. Barium carbonate is often used as the raw material for manufacture of other barium chemicals. Because of its poisonous properties, it is often a constituent in rat poisons.

Barium chloride, besides being a principal source of other barium chemicals, is used to purify salt brines for use in chlorine and sodium hydroxide manufacture. Other uses of this chemical are: production of coatings for photographic paper; as a flux in making magnesium alloys; as a finish for white leather; as material for conversion to blanc fixe; in manufacture of lake colors; in fixation of acid dyes on inert bases; as water softener in boiler compounds; as a chemical reagent in sulphur determinations; and in medicinal preparations.

The salt, barium nitrate, is used to manufacture barium hydroxide or barium dioxide. It is used in pyrotechnics for green flares and other signal lights and in certain explosive mixtures. Like barium chloride, it has medicinal properties.

At present, barium hydroxide has small commercial usage in the United States. In the beet sugar industry, its use has been supplanted by the non-toxic strontium hydroxide. Strontium carbonate has likewise replaced barium carbonate in the same industry because it is more readily reduced to the oxide.

Barium sulphide is used principally as an intermediate compound in manufacture of other barium compounds. Mixed with lime, it is used as a depilatory in the leather industry. In the rubber industry, it is employed in vulcanizing and ''loading'' gutta percha. Sodium sulphide obtained by adding a sodium salt to a barium sulphide solution is used in the dye trade in preparation of sulphur black and other sulphur colors.

Other barium compounds are used as follows: barium oxide in case hardening steel; barium dioxide (or peroxide) in manufacturing hydrogen peroxide, oxygen (by the Brin process), and bleaching agents; barium chromate in yellow pigments and safety matches; barium chlorate in pyrotechnics and dyes; barium acetate as a chemical reagent; barium cyanide in metallurgy; barium ethyl sulfate in organic preparations; barium fluorite as a constituent of embalming fluids, enamels and antiseptic preparations; barium iodide and bromide for manufacture of other halogen compounds; barium manganate (''Rosenstiehls green'' or Bottgers green'') for use in green pigments; and barium sulphocyanate or sulphocyanide in manufacture of aluminum and potassium sulphocyanate.

Small amounts of barium metal used in sparkplug electrode alloys increases their ''sparking'' efficiency. The discovery in 1939 of isotopes of barium and lanthanum in products resulting from neutron bombardment of uranium has resulted in further research on barium in relation to nuclear fission.

HISTORY

One of the first references to barite in literature appeared early in the seventeenth century. ''Heavy spar'' found near the city of Bologna, Italy, was experimented with by a shoemaker and alchemist named Vicenzo Casciarolo who noticed that the ''rock,'' mixed with combustible material and heated to redness, left a calcined product which emitted a phosphorescent glow. Thus, barite came to be known as ''Bologna stone'' or ''Bologna phosphorus.'' As a result of publicity given Casciarolo's discovery, an account of the ''Bologna stone'' or ''De lapide illuminable'' appeared in volume 4 of the finely illustrated 1642 folio edition of the ''Complete Works of Ulise Aldrovandi.'' Aldrovandi was Professor of Pharmacognosy at Bologna and founder of a great botanical garden and museum and library in that city.

Jacobo Bartolomeo Beccari and other Bologna scientists thought they found sulphur and an alkaline salt in the mineral during an analysis of ''Bologna stone'' in 1711. The mineral was then considered to be a kind of gypsum until the Swedish scientist Axel Fredric Cronstedt classified it as a separate species. Cronstedt, who lived from 1722-1765, also discovered nickel.

In 1750, Marggraf produced sulphuric acid from barite, but believed the base to be lime. Scheele, in his famous investigations of pyrolusite (published in 1774), discovered baryta and found that a white, nearly insoluble precipitate could be obtained from it from sulphuric acid or vitriol solutions. Shortly after finding the new alkali as an associate of pyrolusite, a specimen of pyrolusite was received by Scheele from Tobern Bergman to which some peculiar crystals were attached. He sent some of the crystals to J. G. Gahn who found their composition to be the same as that of ''heavy spar'' or ''Bologna stone.'' Gahn's discovery of the composition of barite opened to chemists an abundant source of baryta which, previously, had been a great rarity. Baryta (BaO) was first distinguished from lime (CaO) by Scheele in 1779. He prepared it from the natural mineral barite.

Metallic barium was first prepared by Sir Humphrey Davy in 1808. His isolation of the alkali metals was a brilliant achievement and soon led to discovery of the alkali-earth metals and ultimately to a host of other rare metals. Isolation of barium is sometimes attributed jointly to the work of Sir Humphrey Davy and to Berzelius and De Pontin. In 1808, Berzelius, a Swedish chemist and scientist, wrote Davy that he had decomposed lime by mixing it with mercury and electrolyzing the mixture. He wrote that he had also been successful in preparing barium amalgam by the same method. With the help of these suggestions, Davy finally worked out a method of isolating the metals themselves. He acknowledged his indebtedness to Berzelius and De Pontin in correspondence passing between them in July of 1808.

Barite mining in the United States probably first began in 1845 when a small deposit in Prince William County, Virginia, was operated. The next state to produce barite is said to be Missouri where mining was carried on as far back as 1860. During the early years of barite production, Virginia was the leader, but by 1893, Missouri was producing equal amounts. California barite was first discovered and mined in the eighties at El Portal in Mariposa County. The earliest recorded production from Canada was from Nova Scotia between 1865 and 1870.

BIBLIOGRAPHY

Clark, F. W., The data of geochemistry: U. S. Geol. Survey Bull. 770, 592 pp., 1924.

Edmonson, R. S., Barite deposits in Virginia: Am. Inst. Min. Met. Eng. Tech. Pub. 725, 5 pp., 1936.

Fitch, A. A., Barite and witherite from El Portal, Mariposa County, California: Am. Mineralogist, vol. 16, no. 10, pp. 461-468, October 1931.

Kraus, E. H., Hunt, W. F. and Ramsdell, L. S. Mineralogy, New York, McGraw Hill Book Co., 1936.

Minerals Yearbook: U. S. Bur. Mines. Published each year; contains a chapter on barite and barium products.

Murdock, Joseph, and Webb, Robert W., Minerals of California: California Div. Mines Bull. 136, 402 pp., 1948. Briefly describes occurrences.

Ries, H., Barite: Economic geology, pp. 254-261, New York, John Wiley and Sons, 1937. Has extensive bibliography.

Santmyers, R. M., Barite and barium products: U. S. Bur. Mines Inf. Circ. 6221, 55 pp., 1930.

Santmyers, R. M., Barium products: U. S. Bur. Mines Inf. Circ. 6223 (revised), 26 pp., 1930. Contains a list of plants producing ground barite and barium chemicals.

Seferblom, W., Properties of inorganic substances, pp. 35-52, New York, Chemical Catalogue Pub. Co., 1927.

Spence, H. S., Barium in Canada: Canada Dept. Mines, Mines Branch no. 570, 74 pp., 1922.

Taggart, A. F., Handbook of mineral dressing, New York, John Wiley and Sons, 1945.

Tarr, N. A., Barite deposits of Missouri: Univ. Missouri Studies, vol. 3, no. 1, pp. 75-100, 1918.

Weeks, S. M., Discovery of the elements; Jour. Chem. Education, Easton, Pennsylvania, 1945.

Weigel, W. M., Barium minerals; in Industrial Minerals and Rocks, pp. 97-110, Am. Inst. Min. Met. Eng., 1937.

Weigel, W. M., Barite industry in Missouri: Am. Inst. Min. Met. Eng. Tech. Pub. 201, pp. 1-26, 1929.

Whitlatch, G. I., Barite: Tennessee Div. Geol. Markets Circ. 7, 2d ed., 1938. Brief general data on barite and barium products.

PENN MINE SLAG DUMP AND MINE WATER, CALAVERAS COUNTY, CALIFORNIA*

By Frank J. Wiebelt ** and Spangler Ricker **

OUTLINE OF REPORT

	Page
Summary	99
Introduction	99
Acknowledgments	99
History	102
Physical features	102
Work performed by Bureau of Mines	102
Metallurgy	103
Mine water	104

Illustrations

Figure 1.	Surface plan, Penn mine, Calaveras County	100
2.	Assay map, Penn mine slag dump, Calaveras County	101

SUMMARY

The Penn mine slag dump is situated at the old Penn Mining Company's smelter site in Calaveras County, California. It is an accumulation of slag from approximately 800,000 tons of copper-zinc ore smelted before operations were discontinued in 1919.

Composite samples of the dump from four shafts aggregating 153.5 feet and 575 linear feet of trenching showed the zinc and copper content to be 6.47 percent and 0.37 percent, respectively. Metallurgical tests by the Waelz process recovered only 25 percent of the zinc.

Samples of the mine water that had accumulated since the mine was unwatered in 1938 were taken from points 51.5 feet and 93.5 feet below the water level in No. 2 shaft. Analysis showed 34.2 pounds of zinc per 1,000 gallons. The mine was subsequently unwatered by lessees. In depth the zinc content of the water decreased to inappreciable amounts, and recovery of the zinc was not attempted.

INTRODUCTION

The possibility of zinc and copper production from the Penn mine slag dump and Penn mine water was reported by D. W. Butner, a Bureau of Mines engineer in June 1942. Sampling projects were subsequently planned and were executed during September and October of the same year.

ACKNOWLEDGMENTS

In its program of investigation of mineral deposits, the Bureau of Mines has as its primary objective, the more effective utilization of our mineral resources to the end that they make the greatest possible contribution to national security and economy. It is the policy of the Bureau to publish the facts developed by each project as soon as practicable after its conclusion. The Mining Branch, Lowell B. Moon, chief, conducts preliminary examinations, performs the actual investigative work, and prepares the final report. The Metallurgical Branch, O. C. Ralston, chief, analyzes samples and performs beneficiation tests.

Field work on this project was directed by Spangler Ricker of the California field office, which is under the general supervision of A. C.

---

* Reprinted from Bureau of Mines Report of Investigations 4224.

** Mining engineers, Reno Branch, Mining Division.

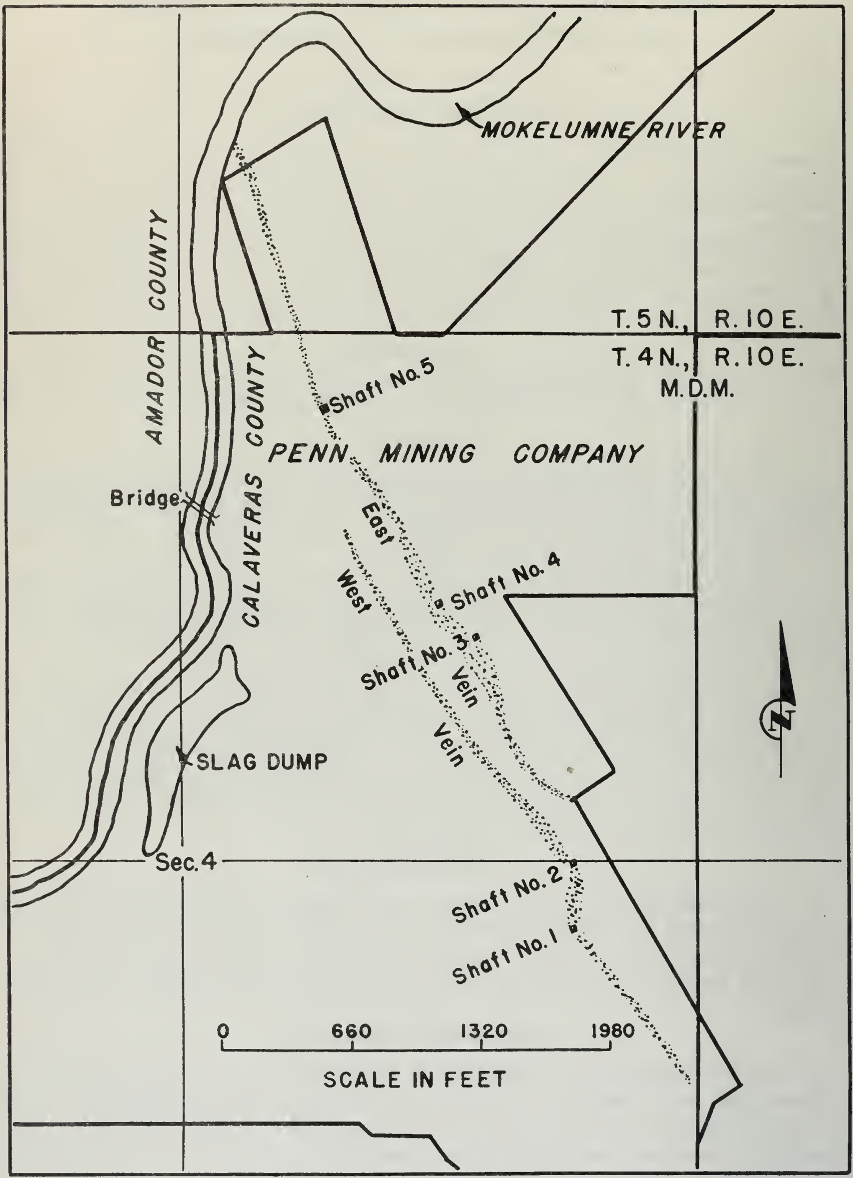
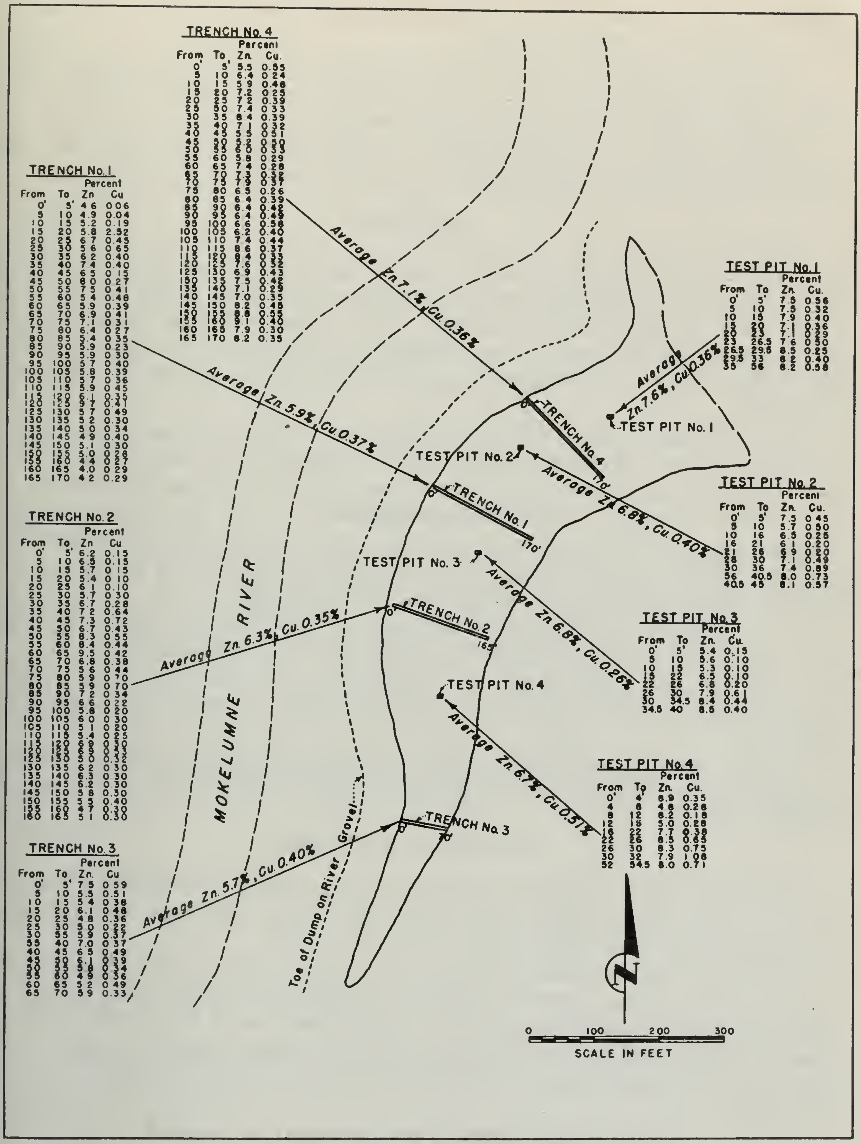


Figure 1. Surface plan, Penn mine, Calaveras County, California


Average Zn. 7.1%, Cu. 0.36%
Average Zn. 5.9%, Cu. 0.37%
Average Zn. 6.3%, Cu. 0.35%
Average Zn. 5.7%, Cu. 0.40%
Average Zn. 7.6%, Cu. 0.36%
Average Zn. 6.8%, Cu. 0.40%
Average Zn. 6.6%, Cu. 0.26%
Average Zn. 6.7%, Cu. 0.51%
TRENCH No. 4
TRENCH No. 1
TRENCH No. 2
TRENCH No. 3
0'
170'
165'
70'
TEST PIT No. 1
TEST PIT No. 2
TEST PIT No. 3
TEST PIT No. 4
MOKELUMNE RIVER
Toe of Dump on River Gravel
0 100 200 300
SCALE IN FEET

TRENCH No. 4

From	To	Percent Zn.	Percent Cu.
0'	5'	5.5	0.55
5	10	6.4	0.24
10	15	5.9	0.48
15	20	7.2	0.25
20	25	7.2	0.39
25	30	7.4	0.33
30	35	8.4	0.39
35	40	7.1	0.32
40	45	5.5	0.51
45	50	5.2	0.50
50	55	6.0	0.33
55	60	5.8	0.29
60	65	7.4	0.28
65	70	7.3	0.38
70	75	7.9	0.37
75	80	6.5	0.26
80	85	6.4	0.39
85	90	6.4	0.42
90	95	6.4	0.49
95	100	6.6	0.58
100	105	6.2	0.40
105	110	7.4	0.44
110	115	8.6	0.37
115	120	8.4	0.33
120	125	7.6	0.32
125	130	6.9	0.43
130	135	7.5	0.42
135	140	7.1	0.29
140	145	7.0	0.35
145	150	8.2	0.46
150	155	8.8	0.55
155	160	9.1	0.40
160	165	7.9	0.30
165	170	8.2	0.35

TRENCH No. 1

From	To	Percent Zn	Percent Cu
0'	5'	4.6	0.06
5	10	4.9	0.04
10	15	5.2	0.19
15	20	5.8	2.52
20	25	6.7	0.45
25	30	5.6	0.65
30	35	6.2	0.40
35	40	7.4	0.40
40	45	6.5	0.15
45	50	8.0	0.27
50	55	7.5	0.41
55	60	5.4	0.48
60	65	5.9	0.39
65	70	6.9	0.41
70	75	7.1	0.31
75	80	6.4	0.27
80	85	5.4	0.35
85	90	5.9	0.23
90	95	5.9	0.30
95	100	5.7	0.40
100	105	5.8	0.39
105	110	5.7	0.36
110	115	5.9	0.45
115	120	6.1	0.35
120	125	9.7	0.41
125	130	5.7	0.49
130	135	5.2	0.30
135	140	5.0	0.34
140	145	4.9	0.40
145	150	5.1	0.30
150	155	5.0	0.28
155	160	4.4	0.27
160	165	4.0	0.29
165	170	4.2	0.29

TRENCH No. 2

From	To	Percent Zn	Percent Cu
0'	5'	6.2	0.15
5	10	6.5	0.15
10	15	5.7	0.15
15	20	5.4	0.10
20	25	6.1	0.10
25	30	5.7	0.30
30	35	6.7	0.28
35	40	7.2	0.64
40	45	7.3	0.72
45	50	6.7	0.43
50	55	8.3	0.55
55	60	8.4	0.44
60	65	9.5	0.42
65	70	6.8	0.38
70	75	5.6	0.44
75	80	5.9	0.70
80	85	5.9	0.70
85	90	7.2	0.34
90	95	6.6	0.22
95	100	5.8	0.20
100	105	6.0	0.30
105	110	5.1	0.20
110	115	5.4	0.25
115	120	6.8	0.30
120	125	6.9	0.33
125	130	5.0	0.32
130	135	6.2	0.30
135	140	6.3	0.30
140	145	6.2	0.30
145	150	5.8	0.30
150	155	5.5	0.40
155	160	4.7	0.30
160	165	5.1	0.30

TRENCH No. 3

From	To	Percent Zn.	Percent Cu
0'	5'	7.5	0.59
5	10	5.5	0.51
10	15	5.4	0.38
15	20	6.1	0.48
20	25	4.8	0.36
25	30	5.0	0.22
30	35	5.9	0.37
35	40	7.0	0.37
40	45	6.5	0.49
45	50	6.1	0.39
50	55	5.8	0.34
55	60	4.9	0.36
60	65	5.2	0.49
65	70	5.9	0.33

TEST PIT No. 1

From	To	Percent Zn.	Percent Cu.
0'	5'	7.5	0.56
5	10	7.5	0.32
10	15	7.9	0.40
15	20	7.1	0.36
20	23	7.1	0.29
23	26.5	7.6	0.30
26.5	29.5	8.5	0.25
29.5	33	8.2	0.40
33	36	8.2	0.58

TEST PIT No. 2

From	To	Percent Zn.	Percent Cu.
0'	5'	7.5	0.45
5	10	5.7	0.50
10	16	6.5	0.28
16	21	6.1	0.20
21	26	6.9	0.20
26	30	7.1	0.49
30	36	7.4	0.89
36	40.5	8.0	0.73
40.5	45	8.1	0.57

TEST PIT No. 3

From	To	Percent Zn.	Percent Cu.
0'	5'	5.4	0.15
5	10	5.6	0.10
10	15	5.3	0.10
15	22	6.5	0.10
22	26	6.8	0.20
26	30	7.9	0.61
30	34.5	8.4	0.44
34.5	40	8.5	0.40

TEST PIT No. 4

From	To	Percent Zn.	Percent Cu.
0'	4'	8.9	0.35
4	8	4.8	0.28
8	12	8.2	0.18
12	16	5.0	0.28
16	22	7.7	0.38
22	26	8.5	0.65
26	30	8.3	0.75
30	32	7.9	1.08
32	34.5	8.0	0.71

FIGURE 2. Assay map, Penn mine slag dump, Calaveras County, California

Johnson, chief of the Reno Division, Mining Branch. Frank J. Wiebelt was in charge of work in the field.

Acknowledgment is made to the engineers of the Salt Lake City and Reno metallurgical stations, particularly H. C. Poole and A. C. Rice, for tests and analytical work done on the samples.

Alfred Busey, manager of the operations during the time the slag dump accumulated, provided the Bureau with much useful data.

HISTORY

The Penn mine area was producing copper ores as long ago as the early sixties. A blast furnace was operated for some years previous to 1910, when reverberatory furnaces were installed. These were operated continuously to 1919, when they closed down because of low metal prices. Since that year, all smelting equipment has been removed from the property.

Zinc was associated with the copper ore treated, but only the copper content was recovered. A total of 800,000 tons of ore is reported to have been treated, and most of its zinc content should be in the slag dump.

After cessation of smelting operations in 1919, the mine was kept pumped out until 1926, when the pumps were removed and the mine filled with water. In 1928, and again in 1934, lessees attempted to reopen the mine, but both trials were underfinanced and failed.

A. P. Busey Jr., unwatered the mine to the bottom of shaft 2 in 1938, but, owing to financial difficulties, the project was again abandoned.

During the latter part of World War II, the mine was again unwatered by lessees, and a creditable record of production is being achieved.

The Penn property is owned by the Penn Mining Company, which is locally represented by Robert Searls, 225 Bush Street, San Francisco, California.

PHYSICAL FEATURES

Mine and slag dump are in the southern corner of Calaveras County, in sec. 4, T. 4 N., R. 10 E., M.D. The altitude is 300 feet, and physical conditions favor year-round operation.

The area is accessible by motor transport from Valley Springs by way of Campo Seco over 4 miles of oiled-surface road and 1 mile of graveled road. Valley Springs is a small town on a branch line of the Southern Pacific Railway. Stockton, the important supply center of the district, is 35 miles distant and is connected with Valley Springs by paved highways.

WORK PERFORMED BY BUREAU OF MINES

Figure 1 shows the relationship of the slag dump to the mine. Figure 2 shows the plan of the dump and detailed sampling and assay results.

The dump was started along a hillside and was filled out toward the edge of the Mokelumne River. It is 1,100 feet long and ranges in width from 25 to 200 feet. The surface area is approximately 168,000 square feet, and the average depth is 40 feet.

Sampling was done by means of shafts and trenches. Four shafts 6 by 5 feet, totaling 153.5 feet, were sunk, and four trenches totaling 575 linear feet were made across the surface; 150 samples were taken. The samples represented 5-foot lengths, and the minimum weight of a sample was 50 pounds. Assay results and calculations are shown in the following table:

Analyses and computed metal content of Penn mine slag dump

	Length or depth, feet	Zinc percent	Copper, percent	Length by percent	
				Zinc	Copper
Shaft:					
1	36	7.6	0.36	274	13.0
2	43	6.8	.40	292	17.2
3	40	6.8	.26	272	10.4
4	34.5	6.7	.51	231	17.6
Trench:					
1	170	5.9	.39	1,003	66.3
2	165	6.3	.35	1,039	57.7
3	70	5.7	.40	399	28.0
4	170	7.1	.37	1,207	62.9
Total and averages	728.5	6.47	.37	4,717	273.1

METALLURGY

Because of the small amount of slag available and its low zinc content, the Waelz process appeared to be the only feasible method of treating it. In this process the material is heated with coke to 1,100° to 1,200° C. in a rotary kiln to reduce the zinc to metal, which vaporizes from the charge and is reoxidized immediately to zinc oxide by the gases that pass through the kiln; the zinc oxide fume is carried out by these gases and is collected in a baghouse. In order that the process may be successful, the charge must not fuse at the temperatures involved.

Waelz volatilization tests were made by the Bureau in a batch-type, gas-fired, rotary kiln on a composite sample of the slag with the following analysis:

	Percent
Zn	5.65
Pb	.1
Fe	27.1
SiO_2	31.8
CaO	8.4
MgO	3.2
Al_2O_3	6.1

The slag was crushed to minus 20-mesh. In the first test, an amount of coke equal to 20 percent of the weight of slag was used, and the charge fused at a temperature lower than that required for rapid volatilization of the zinc. Other tests were made with 20 percent coke and 20 percent limestone and with 40 percent of each, but results were still poor, as shown by the following table:

Volatilization test on Penn slag

Test	Charge, pounds			Temperature, °C.	Time, hours	Percent Zn in residue	Percent of Zn volatilized
	Slag	Limestone	Coke				
1	105		21	1,010-1,040	1.0	4.4	22
2	100	20	20	1,000-1,135	1.0	1.0	26
3	80	32	32	1,010-1,075	1.5	1.5	29

In each instance the charge fused and slagged to the furnace lining, so that the weight of residue could not be determined. The percentage of zinc volatilized was calculated, therefore, on the assumption that the limestone was completely calcined and the coke completely burned off, and thus represents a maximum value.

MINE WATER

According to reports, the mine water during the principal production period of the mine carried 20 pounds of copper per 1,000 gallons of water in winter and 6 pounds to 8 pounds of copper per 1,000 gallons in summer. The flow was 19 gallons per minute. The copper was recovered by the usual method of precipitating on scrap iron in launders.

During the unwatering operations in 1938, the water pumped at the rate of 250 gallons per minute for the first 3 hours contained 15 to 16 pounds of copper per 1,000 gallons. The copper content thereafter declined rapidly to not much more than a trace, and the zinc content increased to about 70 pounds per 1,000 gallons.

In 1942, samples by the Bureau of Mines from the water level in shaft 4 contained 2 pounds of zinc and 5 pounds of copper per 1,000 gallons. Samples from points 51.5 and 93.5 feet below water level in shaft 2 showed a zinc content of 34.2 pounds per 1,000 gallons and a copper content of 0.24 pounds per 1,000 gallons. A sample of water from the old water-disposal pond showed zinc and copper contents of 28.8 pounds and 0.54 pound per 1,000 gallons, respectively.

Sampling of water in shaft 2 was accomplished by lowering a 1-inch pipe inside the 5-inch lead-lined pump-discharge column that extended to the 600-foot level. An obstruction in the 5-inch line prevented lowering of the 1-inch pipe below the 93.5-foot water level. Enough water was pumped prior to taking the sample to insure a sample from the 600-foot level. However, if the pipe was broken below the obstruction, the depth points of the two samples would be 51.5 feet and 93.5 feet below the water level.

Since the sampling, the water has been lowered to the 1,100-foot level, and it is reported that the zinc content diminished to an inappreciable amount as pumping progressed.

The data obtained from this sampling and old records indicate the hazards involved in taking water samples from old water-filled mines unless representative samples can be taken from all sections.

Samples were sent to the Experimental Laboratory of the Bureau of Mines, Salt Lake City, for zinc-recovery tests. The results were as follows:

Sample analysis

Sample location	Grams per liter									
	Zn	Cu	Fe	MgO	CaO	Na_2O	Al_2O_3	SO_4	Cl	Pb, P, K_2O
Pond	3.45	0.066	4.34	1.85	0.7	9.08	3.64	40.0	0.46	Nil
#2 shaft 51.5 feet	4.05	.033	7.28	1.50	0.6	4.06	2.02	32.1	.049	Nil
#2 shaft 93.5 feet	4.16	.025	7.35	1.69	0.6	4.49	1.83	32.2	.047	Nil

Summary sheet
Methods investigated for recovery of zinc

Method	Grade of product, percent		Percent extraction of Zn	Reagents employed, lb./ton
	Zn	Fe		
Straight evaporation	6.95	13.65	100.0	
Oxidizing and precipitating iron below neutral, then adding excess alkali to precipitate zinc. (Virtually all of zinc was occluded in the iron precipitate, and no successful separation was made.) (Analyses shown are of the "iron precipitate."	2.3	2.3	87.5	MnO_2 6 $CaCO_3$ 260 (For Fe pptn. only)
	3.8	7.45	95.2	MnO_2 6 CaO 80
	9.75	9.35	82.7	MnO_2 6 NaOH 32
Gassing 250 cc. for 1 minute with NH_3	15.05	14.2	40.4	No record
Gassing with H_2S for 15 minutes	50.4	1.45	19.1	No record
Gassing with H_2S for 25 minutes. Na_2S added as needed to keep pH above 2.3	50.6	2.05	59.6	H_2S 10.8 Na_2S 5.0
Aerated over $CaCO_3$, filter off Fe precipitate (0.3 percent zinc, 36.0 percent iron). Precipitate zinc with Na_2CO_3	19.1	19.8	67.6	Na_2CO_3 12.9 $CaCO_3$ 100.0 (estimated)

As the mine water was high in iron and alumina, bulk precipitation gave low-grade products and high reagent consumption. No completely successful method was found that would remove zinc from the mine water within economic limits. The most promising results were obtained by gassing solutions with hydrogen sulfide. With proper pH control, almost 60 percent of the zinc was recovered as a 50.6 percent product.

In addition to the methods previously summarized, the following methods were tried.

1. *Precipitation with soaps and fatty acids.* By this method, up to 10 pounds of soap or fatty acid per ton of mine water failed to remove more than one-quarter of the zinc.

2. *Removing the zinc by passing the mine water through zeolite with subsequent recovery in a brine solution.* This method did remove a very small amount of zinc and iron but not enough to encourage further testing.

3. *Removal by bentonite.* Preliminary tests showed that mechanical difficulties, such as settling and filtering, would preclude any practical plant operation.

DIVISION OF MINES
PUBLICATIONS ISSUED SEPTEMBER 1, 1948, TO NOVEMBER 30, 1948 *

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

Vol. 44, no. 4, October 1948, pp. 321-524, pls. 52-59, 20 figs. *Price 75¢.*

Contains: Economic aspects of mercury production in California, by C. R. King, pp. 327-334, 2 figs.; Current and recent mining activities in the Redding district (Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Shasta, Siskiyou, Tehama, Trinity Counties), by J. C. O'Brien, pp. 335-378, pls. 52-55; The spectrograph and polarograph, by John Herman, pp. 379-409, pls. 56-59, 18 figs.; Public Resources Code, pp. 411-415; U. S. Atomic Energy Commission announces program to stimulate production of domestic uranium, pp. 417-425; Publications of the California State Division of Mines, by Elisabeth L. Egenhoff, Beth Collins, and Mary-Louise Burgess, pp. 427-516; Index to volume 44, pp. 517-524.

Vol. 45, no. 1, January 1949, pp. 1-116, pls. 1-8, 4 figs. *Price 75¢.*

Contains: Annual report, Division of Mines, for the ninety-ninth fiscal year, July 1, 1947, to June 30, 1948, by Olaf P. Jenkins, pp. 7-29; Quicksilver deposits of the Oakville district, Napa County, California, by Philip F. Fix and C. Melvin Swinney, pp. 31-46, pls. 1-3, 2 figs.; Mines and mineral resources of Tuolumne County, California, by Clarence A. Logan, pp. 47-83, pls. 4-8; Barium, by W. B. Winston, pp. 85-97; Penn mine slag dump and mine water, Calaveras County, California, by Frank J. Wiebelt and Spangler Ricker (reprint), pp. 99-105, 2 figs.; Division of Mines publications issued September 1, 1948, to November 30, 1948, pp. 107-108; Map symbols used in publications of the U. S. Geological Survey, pp. 109-116.

BULLETINS

140. Geology of the Tesla quadrangle, California, by Arthur S. Huey. 1948. 75 pp., 11 pls., 3 figs. *Price $1.50 (California residents please add 4¢ sales tax).*

Contains: Colored geologic map on topographic base of Tesla quadrangle, scale 1:62,500; Topographic map of Tesla quadrangle with red overprint showing mineral deposits, section lines, and water-supply tunnel, scale 1:62,500; Structure sections across Tesla quadrangle.

141. Geologic guidebook along Highway 49—Sierran gold belt—the Mother Lode country. 1948. 164 pp., 2 pls., 221 figs., 10 maps. *Price $1.00 (California residents please add 3¢ sales tax).*

Contains: Preface, by Olaf P. Jenkins, p. 7; Publications consulted, p. 8; Sierran roads of today and yesterday, by Dorothy G. Jenkins, pp. 9-12, 2 figs.; The discovery of gold in California, by Donald C. Cutter, pp. 13-17, 2 figs.; History of placer mining for gold in California, by Charles V. Averill, p. 19, 6 figs.; Sierra Nevada province, by Olaf P. Jenkins, p. 21, 1 fig.; Geologic history of the Sierran gold belt, by Olaf P. Jenkins, pp. 23-30, 11 figs.; History of mining and milling methods in California, by C. A. Logan, pp. 31-34, 1 fig.; Geologic maps and notes along Highway 49, by Oliver E. Bowen Jr. and Richard A. Crippen Jr., pp. 35-86, 42 figs., 10 maps; The formation of quartz veins, by John A. Burgess, pp. 87-88, 3 figs.; Mining on Carson Hill, by John A. Burgess, pp. 89-90; Survey of building structures of the Sierran gold belt, 1848-70, by Robert F. Heizer and Franklin Fenenga, pp. 91-164, 168 figs.

---

* First supplement to Publications of the California State Division of Mines to September 1, 1948: California Jour. Mines and Geology, vol. 44, pp. 427-516, 1948. Reprint of the list of publications will be sent free upon request.

MAP SYMBOLS USED IN PUBLICATIONS OF THE UNITED STATES GEOLOGICAL SURVEY

The following list of map symbols has been tentatively adopted for use in publications of the U. S. Geological Survey. It has been the aim to assemble, insofar as possible, symbols that experience has shown are widely needed. Most of those in the list are symbols that are now in common use. It is realized that other symbols will be needed for many special field problems, but it is hoped that the new symbols devised will be as consistent as possible with those on this list. This list is a revision of an earlier one adopted more than 10 years ago by the Geological Survey. The revisions have been made in response to comments by both Survey geologists and others throughout the country and the committee has attempted to bring about greater consistency.

In the use of line symbols for contacts, faults, and folds the solid line is used throughout to denote accurate locations, the dashed line for approximate or indefinite locations, and the dotted line for concealed locations. This is merely an extension to contacts and folds of the standard practice previously applied to faults.

Different kinds of arrows are used to distinguish the various types of linear structures. The barbed arrow is used for flow lines, alinement of minerals and inclusions, etc., and it can also be used for other special types of lineations if such uses are indicated in the explanation on the map. The half-barbed arrow is used to denote direction of relative movement; the spear-point is used for slickensides, grooves, and striations; and the triangular arrow is used for axes of folds. The particular symbols for lineations and for direction of movement have been standard for many years.

On the previous list of Survey map symbols, the term *pitch* was applied to lineations measured in the vertical plane. However, many comments have been received urging that the term *plunge* be used instead, as *plunge* was originally defined by Lindgren in this sense and is so defined in the textbooks of Lindgren and Billings. It was also pointed out that *plunge* has rarely been used in any other sense, and that an increasing number of geologists are adopting Lindgren's definition. For these reasons, the Map Symbol Committee decided to adopt the term *plunge* for the angle measured in the vertical plane. This is the measurement that is usually recorded on geologic maps, but for special structural problems, some geologists prefer to record the angle measured in the plane of the foliation, fault or vein, or in the axial plane of the fold. Lindgren and Billings used *pitch* for this angle. However, *pitch* has been so widely used in both senses and has appeared on so many published maps indicating the vertical angle, that its continued use is likely to lead to further confusion. Therefore, after wide discussion with structural geologists, the Committee decided to abandon the term *pitch* and to suggest the use of the term *rake* for the angle measured in the plane of the structure. This term has been occasionally used to describe the inclination of ore bodies but it has never been clearly defined.

Though this list of map symbols has been prepared primarily for use in publications of the U. S. Geological Survey, it is hoped that it will be helpful to all geologists and will eventually bring about a general uniformity of usage. Copies may be obtained free of charge from the Geologic Map Editor, U. S. Geological Survey, Washington 25, D. C.

MAP SYMBOL COMMITTEE
Ernst Cloos
Lewis B. Pusey
W. W. Rubey
E. N. Goddard, Chairman

MAP SYMBOLS

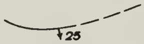
for geologic structure, mineral deposits, and mine workings, for use in publications of the U. S. Geological Survey

(Changes from and additions to the previously adopted Survey list are to be considered tentative for a trial period of two years, during which time the Map Symbol Committee will welcome comments and suggestions. The adoption of this list does not preclude the use of additional symbols or under exceptional circumstances the use of other symbols than those here given for these features, but uniformity and consistency are desirable for clearness).

CONTACTS

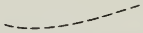
(Boundaries between geologic formations or other rock units)

NOTES



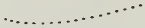
Contact, showing dip
(Dashed where approximately located)

Barbs on dip symbol may be omitted if preferred.



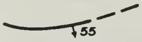
Indefinite contact
(Includes gradational contacts, inferred contacts, and indefinite boundaries of surficial deposits)

To be used only where the zone of indefiniteness is wide with respect to the scale of the map.



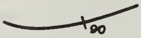
Concealed contact

FAULTS

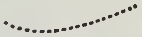


Fault, showing dip
(Dashed where approximately located)

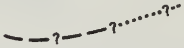
Barbs on dip symbol may be omitted if preferred.



Vertical fault

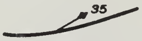


Concealed fault



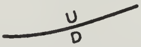
Doubtful or probable fault
(Dotted where concealed)

Question mark indicates uncertainty as to existence of fault



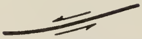
Fault, showing bearing and plunge of grooves, striations, or slickensides

Plunge measured in vertical plane.

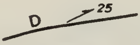


High angle fault
(U, upthrown side; D, downthrown side)

Normal or reverse fault.

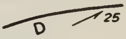


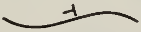
Fault, showing relative
movement



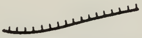
Fault, showing bearing
and plunge of relative
movement of downthrown block

Normal fault is shown.
Reverse fault would
appear thus:

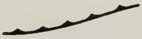




Thrust or low angle reverse fault
(T, upper plate)

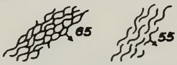


Normal fault
(Hachures on downthrown side)

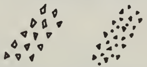


Thrust or reverse fault
(Saw-teeth on side of upper plate)

For use on special
tectonic maps only.



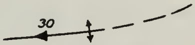
Fault zone or shear zone,
showing dip



Fault breccia

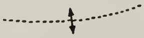
Suitable also as an
overprint for
mylonitized zones and
broad areas of fault
breccia.

FOLDS
(May be shown in color where
structure is unusually
complex)

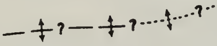


Anticline
(Showing trace of axial plane and
bearing and plunge of axis.
Dashed where approximately located)

If crest line of the
fold is mapped rather
than the trace of the
axial plane, the wording
should be "showing crest
line."

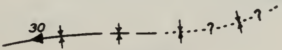


Concealed anticline



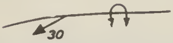
Doubtful or probable anticline
(Dotted where concealed)

Solid, dashed and
dotted as on
anticline

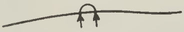


Syncline
(Showing trace of axial plane and
bearing and plunge of axis)

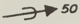
If position of trough is
mapped rather than trace
of axial plane, the wording should be "showing
position of trough."



Overturned anticline
(Showing trace of axial plane, direction of dip
of limbs, and bearing and plunge of axis)

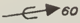


Overturned syncline
(Showing trace of axial plane
and direction of dip of limbs)

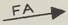


Plunge of minor anticline

Plunge measured in
vertical plane

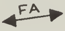


Plunge of minor syncline



Plunge of fold axes

To be used where beds
are too tightly folded
to show individual folds
separately.



Horizontal fold axes

BEDDING

Strike and dip of beds

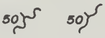
It is suggested that this symbol be used only where the beds are known to be right-side up. If it is not known which side is up, the following symbol is suggested:

Strike and dip of overturned beds

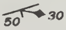
Strike of vertical beds

The position of the 90 can be used to indicate the up side of the beds. If so, this should be stated in the Explanation.

Horizontal beds



Generalized strike and dip
of crumpled, plicated,
crenulated, or undulating beds



Strike and dip of beds
and plunge of slickensides

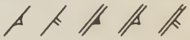
FOLIATION AND CLEAVAGE

Strike and dip of foliation

Strike of vertical foliation

Horizontal foliation

To be used for either primary or secondary foliation. For distinguishing between various types of planar structures, the following additional symbols are suggested:



Strike and dip of cleavage

Strike of vertical cleavage

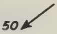
Horizontal cleavage

The type of cleavage mapped should be specified in the Explanation

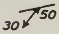
LINEATIONS

(Includes flow lines, alinement of minerals, inclusions, streakings, etc.)

These can also be used for special types of lineation such as intersection of planes, wrinklings, etc., but such uses should be so stated in the Explanation.



Bearing and plunge of lineation



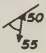
Strike and dip of foliation and plunge of lineation

Vertical lineation

Horizontal lineation

Point of observation is at base of arrow.

Plunge measured in the vertical plane. If the lineation is measured in the plane of the foliation it is suggested that the term rake be used and that the symbol be shown thus:



It is recommended that the term pitch be abandoned as it has been so widely used in both senses and appears on many published maps indicating the vertical angle.

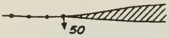
JOINTS

Strike and dip of joints

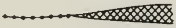
Strike of vertical joints

Horizontal joints

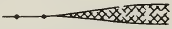
SYMBOLS FOR MINERAL DEPOSITS AND MINE WORKINGS



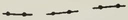
Vein, showing dip



Vein of high-grade ore

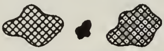


Vein of low-grade ore

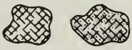


Stringers or veinlets of ore

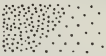
Omit dots if veins are shown in red, except where needed to indicate grade of ore.



High-grade ore



Low-grade ore

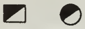


Altered wall rock
(Showing intensity of alteration)

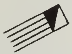
Irregular ore bodies.

SURFACE OPENINGS

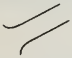
Large-scale maps



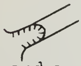
Vertical shaft



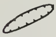
Inclined shaft



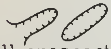
Portal of tunnel or adit



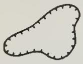
Portal and open cut



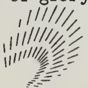
Trench



Small prospect pit
or open cut



Large open pit,
quarry or glory hole



Dump

Small-scale maps

Vertical shaft

Inclined shaft

Portal of tunnel or adit

Trench

X

Small prospect pit
or open cut

Mine, quarry,
glory hole, or large open pit

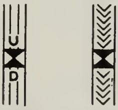
Sand, gravel or
clay pit

UNDERGROUND WORKINGS

Shaft at surface

Shaft going above and
below levels

Bottom of shaft



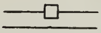
Inclined workings
(Chevrons point down)

Spacing of chevrons can
be used to indicate
steepness of workings.

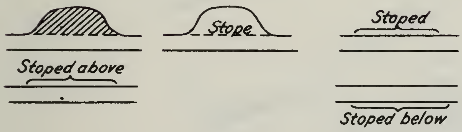
Foot of raise or winze

Head of raise or winze

Raise or winze extending
through level



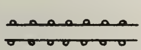
Ore chute



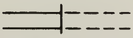
Stopes

Elevation of roof

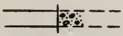
Elevation of floor



Lagging or cribbing
along drift

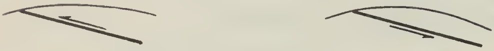


Caved workings or otherwise
inaccessible



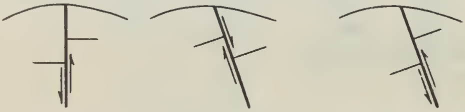
Filled workings

FOR USE ON SECTIONS



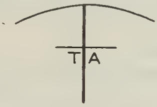
Overthrust Underthrust

Low-angle fault
(Arrow indicates inferred direction of movement of active block)

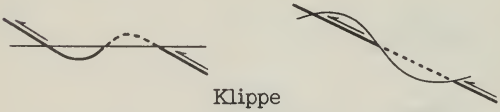


Vertical Normal fault Reverse fault

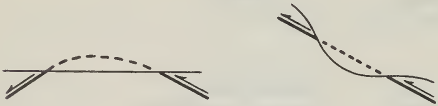
High-angle fault, normal or reverse
(Arrow shows relative direction of movement)



Horizontal movement in shear or tear fault
A, relative movement away from observer;
T, toward observer (symbol may be combined with vertical displacement to show diagonal movement)

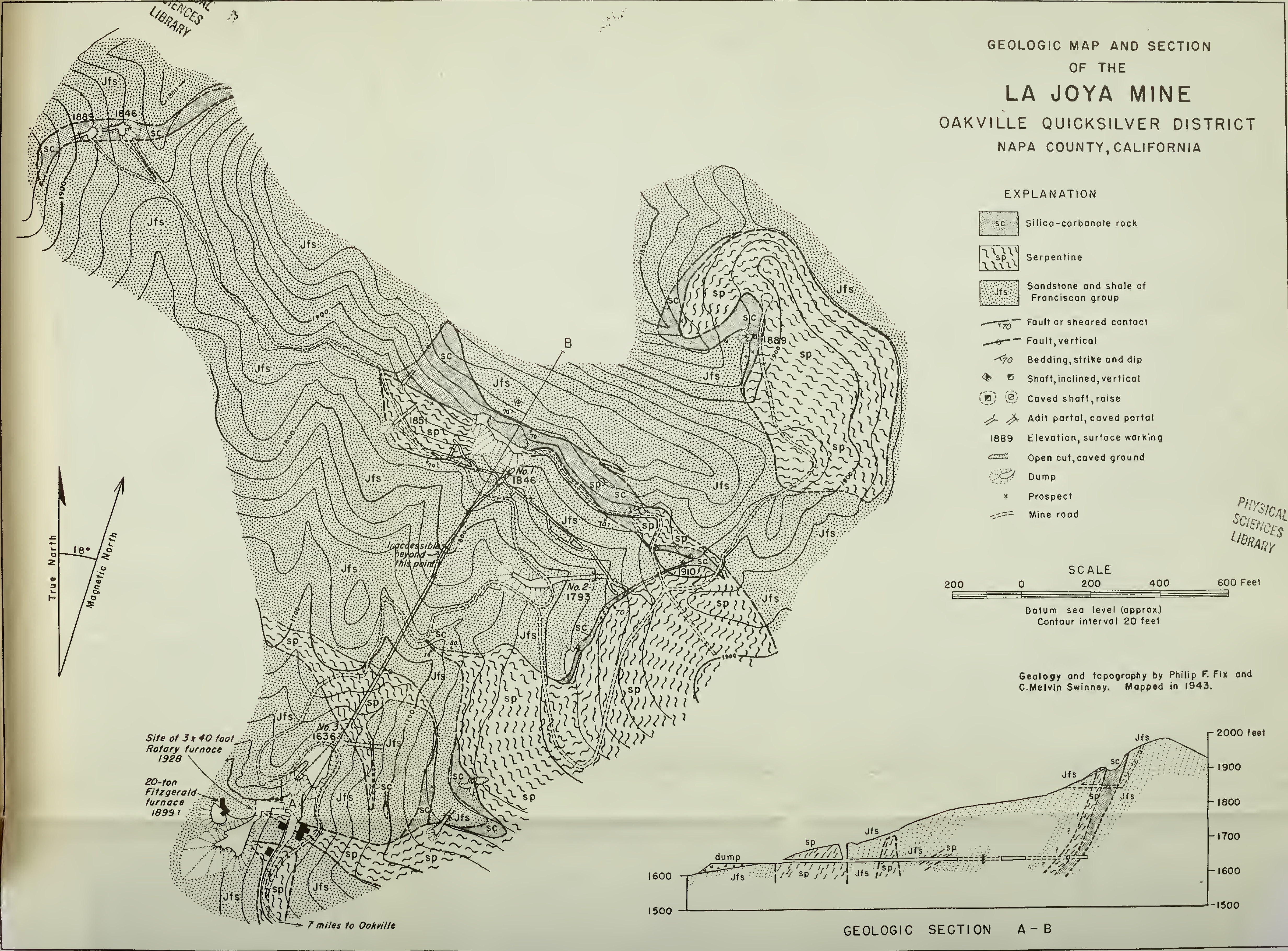


Klippe



Window or fenster

PHYSICAL SCIENCES LIBRARY



GEOLOGIC MAP AND SECTION OF THE

LA JOYA MINE

OAKVILLE QUICKSILVER DISTRICT
NAPA COUNTY, CALIFORNIA

EXPLANATION

sc	Silica-carbonate rock
sp	Serpentine
Jfs	Sandstone and shale of Franciscan group
70	Fault or sheared contact
	Fault, vertical
70	Bedding, strike and dip
	Shaft, inclined, vertical
	Caved shaft, raise
	Adit portal, caved portal
1889	Elevation, surface working
	Open cut, caved ground
	Dump
x	Prospect
	Mine road

SCALE
200 0 200 400 600 Feet
Datum sea level (approx.)
Contour interval 20 feet

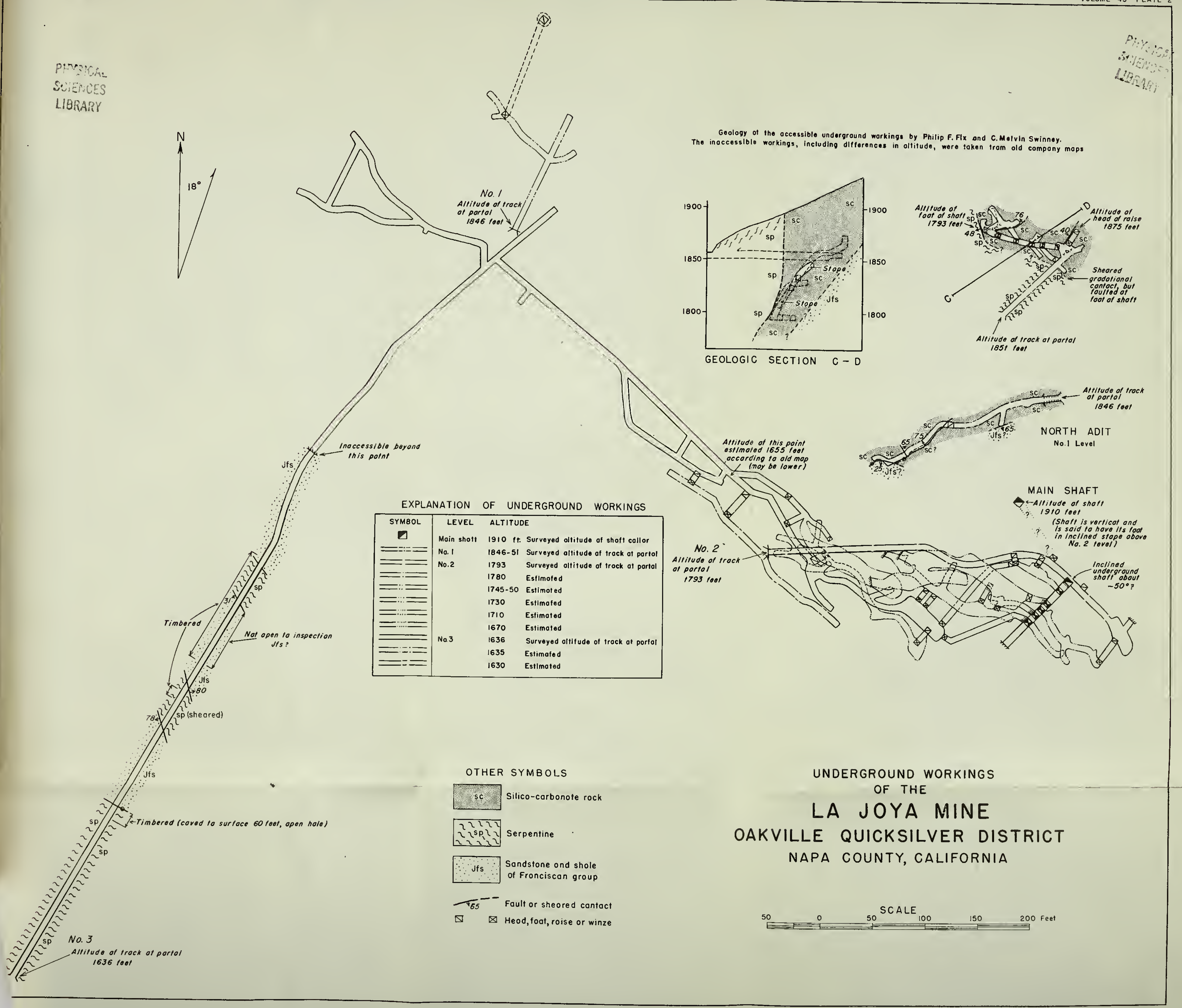
Geology and topography by Philip F. Fix and C. Melvin Swinney. Mapped in 1943.

GEOLOGIC SECTION A – B

PHYSICAL SCIENCES LIBRARY

PHYSICAL
SCIENCES
LIBRARY

PHYSICAL
SCIENCES
LIBRARY


N
18°
No. 1
Altitude of track at portal 1846 feet
Inaccessible beyond this point
Jfs
sp
31
Timbered
Not open to inspection Jfs?
Jfs
80
78
sp (sheared)
Jfs
sp
Timbered (caved to surface 60 feet, open hole)
sp
sp
No. 3
Altitude of track at portal 1636 feet
Altitude of this point estimated 1655 feet according to old map (may be lower)
No. 2
Altitude of track at portal 1793 feet
1900
1850
1800
sc
sp
Stope
Jfs
GEOLOGIC SECTION C – D
Altitude of foot of shaft 1793 feet
48
76
40
D
C
Altitude of head of raise 1875 feet
Sheared gradational contact, but faulted at foot of shaft
Altitude of track at portal 1851 feet
Altitude of track at portal 1846 feet
65
75
25
Jfs?
sc?
NORTH ADIT
No. 1 Level
MAIN SHAFT
Altitude of shaft 1910 feet
(Shaft is vertical and is said to have its foot in inclined stope above No. 2 level)
Inclined underground shaft about –50°?
SCALE
50
0
50
100
150
200 Feet

Geology of the accessible underground workings by Philip F. Fix and C. Melvin Swinney.
The inaccessible workings, including differences in altitude, were taken from old company maps

EXPLANATION OF UNDERGROUND WORKINGS

SYMBOL	LEVEL	ALTITUDE	
◩	Main shaft	1910 ft.	Surveyed altitude of shaft collar
═	No. 1	1846-51	Surveyed altitude of track at portal
═	No. 2	1793	Surveyed altitude of track at portal
═		1780	Estimated
═		1745-50	Estimated
═		1730	Estimated
═		1710	Estimated
═		1670	Estimated
═	No. 3	1636	Surveyed altitude of track at portal
═		1635	Estimated
═		1630	Estimated

OTHER SYMBOLS

sc	Silico-carbonate rock
sp	Serpentine
Jfs	Sandstone and shale of Franciscan group
65	Fault or sheared contact
⊠	Head, foot, raise or winze

UNDERGROUND WORKINGS
OF THE
LA JOYA MINE
OAKVILLE QUICKSILVER DISTRICT
NAPA COUNTY, CALIFORNIA

DIVISION OF MINES
Olaf P Jenkins, Chief

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

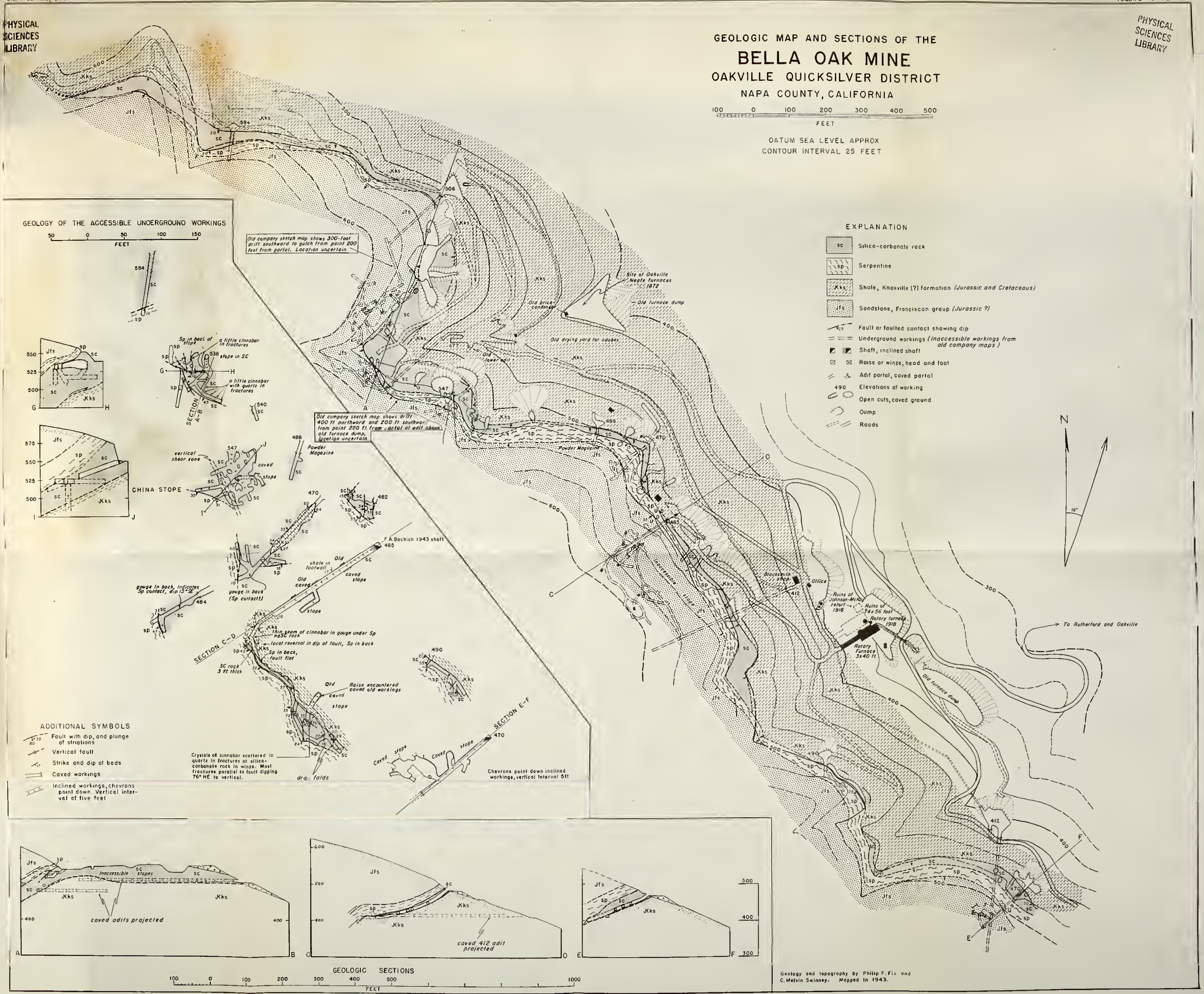
UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

JOURNAL
VOLUME 45 PLATE 3

PHYSICAL
SCIENCES
LIBRARY

PHYSICAL
SCIENCES
LIBRARY

GEOLOGIC MAP AND SECTIONS OF THE
BELLA OAK MINE
OAKVILLE QUICKSILVER DISTRICT
NAPA COUNTY, CALIFORNIA



Old company sketch map shows 300-foot drift southward to gulch from point 200 feet from portal. Location uncertain

Old company sketch map shows drift 400 ft northward and 200 ft. southward from point 220 ft. from portal of adit above old furnace dump. location uncertain.

Crystals of cinnabar scattered in quartz in fractures of silico-carbonate rock in winze. Most fractures parallel to fault dipping 76° NE to vertical.

EXPLANATION

sc	Silica-carbonate rock
sp	Serpentine
Kks	Shale, Knoxville (?) formation *(Jurassic and Cretaceous)*
Jfs	Sandstone, Franciscan group *(Jurassic ?)*
	Fault or faulted contact showing dip
	Underground workings *(Inaccessible workings from old company maps)*
◪	Shaft, inclined shaft
⊠	Raise or winze, head and foot
	Adit portal, caved portal
490	Elevations of working
	Open cuts, caved ground
	Dump
	Roads

ADDITIONAL SYMBOLS

	Fault with dip, and plunge of striations
	Vertical fault
	Strike and dip of beds
	Caved workings
	Inclined workings, chevrons point down. Vertical interval of five feet

GEOLOGIC SECTIONS

100 0 100 200 300 400 500 1000
FEET

Geology and topography by Philip F. Fix and C. Melvin Swinney. Mapped in 1943.

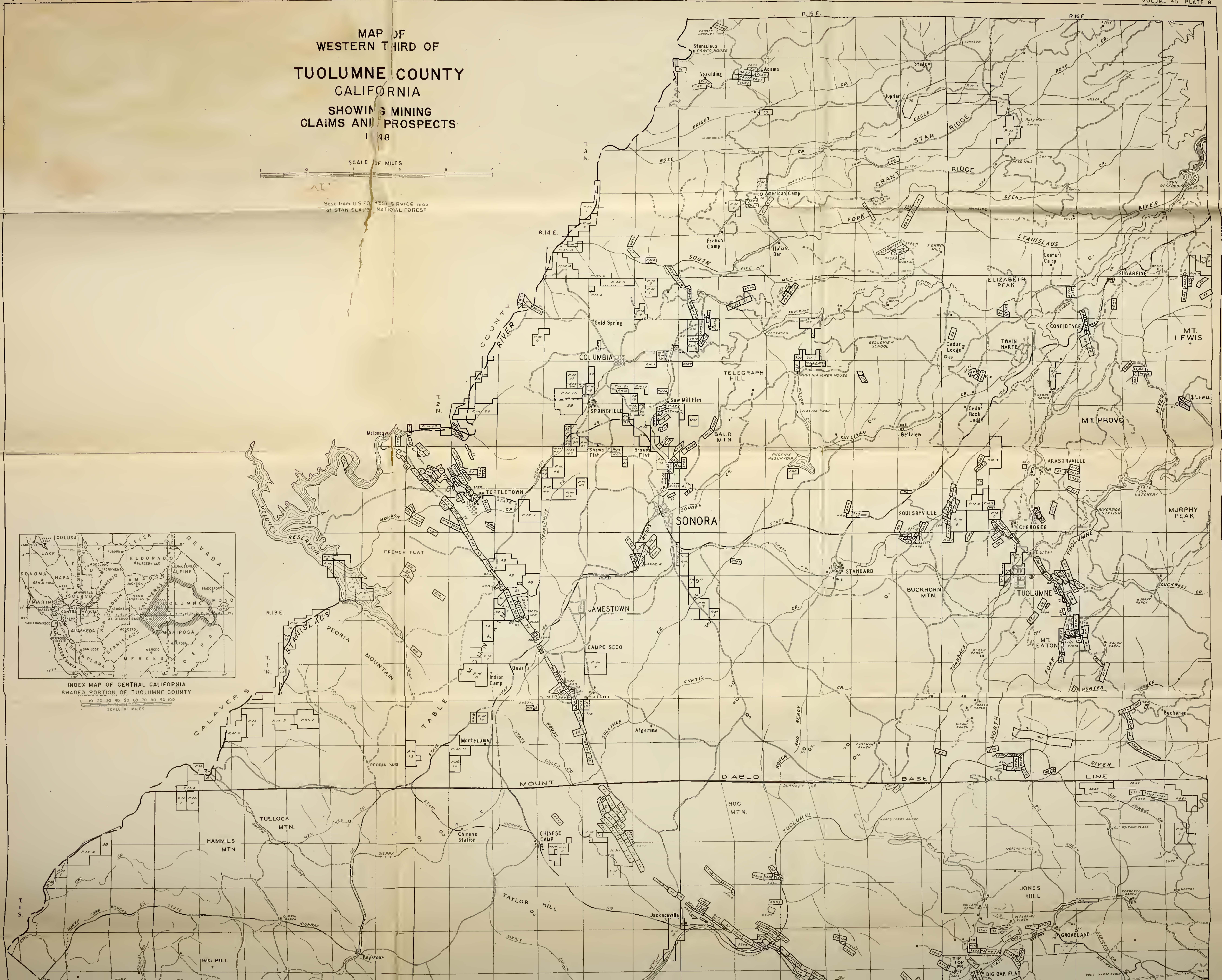
DIVISION OF MINES
OLAF P JENKINS, CHIEF

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES

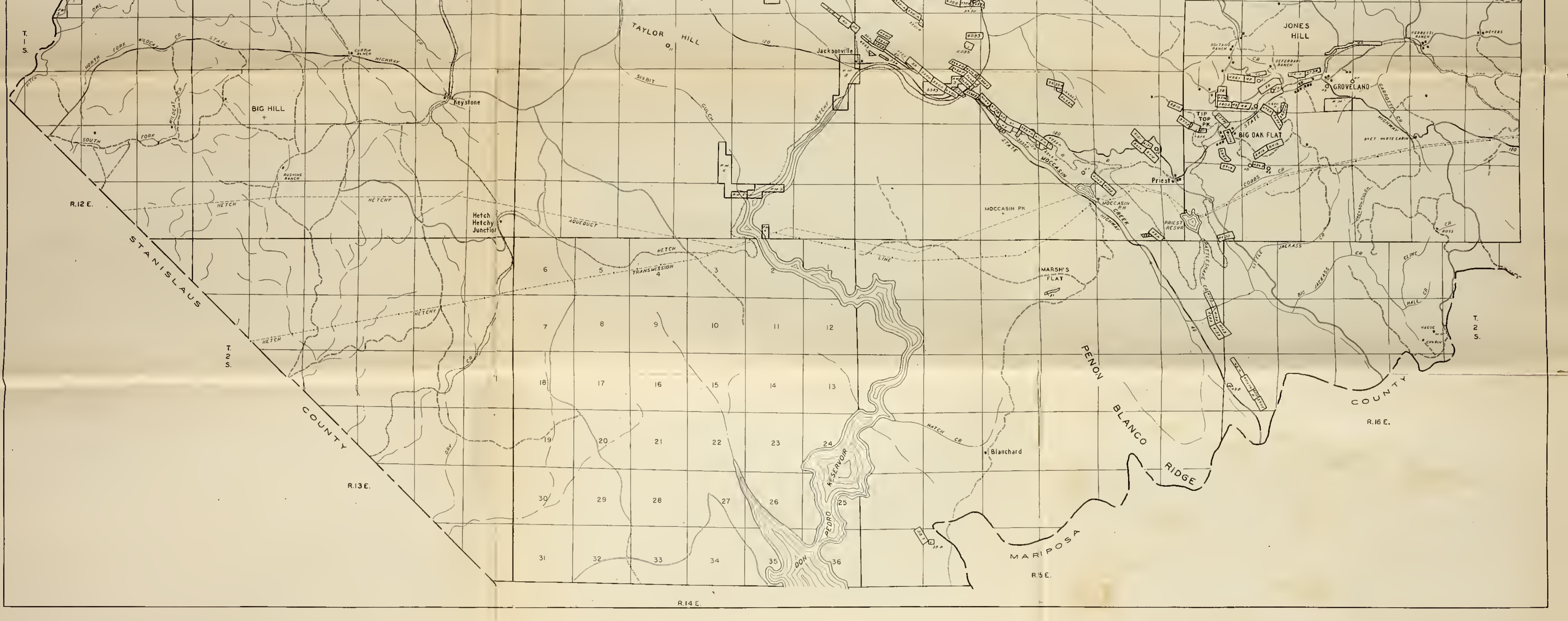
PHYSICAL
SCIENCES
LIBRARY

JOURNAL
VOLUME 45 PLATE 8

MAP OF
WESTERN THIRD OF
TUOLUMNE COUNTY
CALIFORNIA
SHOWING MINING CLAIMS AND PROSPECTS
1948



INDEX MAP OF CENTRAL CALIFORNIA
SHADED PORTION OF TUOLUMNE COUNTY



LIST OF MINES TO ACCOMPANY

TUOLUMNE COUNTY MAP

(Abbreviations: N.P. = not patented; loc. = location)

			Acres
	T. 1 S., R. 12 E., M.D.		
38	Cook Gravel No. 1 placer mine		146.79
PM-1	King placer mine		26.90
PM-2	Buena Vista placer mine (in Stanislaus County)		39.99
PM-3	Lucky Hunch placer mine		16.57
PM-4	Cook Gravel No. 2 placer mine		96.60
	T. 2 N., R. 13 E., M.D.		
51	Bown quartz mine and mill site, N.P.		
53	Gillis & Carrington quartz mine, N.P.		
54	Gillis & Carrington mill site, N.P.		
86	Turner quartz mine		18.16
3971	F. F. McArdle et al. quartz mine		18.19
	T. 1 N., R. 13 E., M.D.		
PM-1	Ruby placer mine		40.00
PM-2	Oliver gravel mine		160.00
PM-3	Stanislaus gravel mine No. 3		160.00
PM-4	Stanislaus gravel mine No. 1		160.00
PM-5	Stanislaus gravel mine No. 2		160.00
PM-6	Grecian Bend gravel mine		120.24
PM-7	Derrick placer mine		40.00
PM-8	Bryns placer mine		40.00
PM-9	Bowery Bar magnesite mine		120.00
PM-10	Monday placer mine		160.00
PM-11	Bumble Bee placer mine		60.00
PM-12	Oscar placer mine		120.00
PM-13	Wilkinson placer mine		50.00
PM-14	Central placer mine		160.00
PM-15	Currie cement mine		30.00
	T. 1 S., R. 13 E., M.D.		
PM-1	Grecian Bend gravel mine		130.24
PM-2	Scorpion gravel mine		71.37
3	McCormick chrome mine		
	T. 3 N., R. 14 E., M.D.		
PM-1	Duck Bar placer mine		120.00
PM-2	Consolidated River placer mine		90.39
PM-3	Good Return placer mine		140.00
PM-4	Gold Springs placer mine		140.00
PM-5	Bell placer mine		150.00
PM-6	*Weiderkind placer mine and Pine Log quartz mine*		20.00
2424	True Business quartz mine		20.66
3694	Magnolia claim, Old Tuolumne Cons. quartz mine		89.13
5677	Ella O. & Morning Star quartz mine		35.446
	T. 2 N., R. 14 E., M.D.		
37	Arbona gold quartz mine		11.34
38	Richards placer mine		140.00
39	Finn placer mine		30.00
40	Waters (Atlas) quartz mine		26.98
41	Petterson quartz mine & mill site		44.05
42	Valparaiso quartz mine & mill site		10.83
43	Fairview quartz mine		5.99
44	Lennan gold quartz mine		4.91
45	Gillis & Carrington quartz mine		16.37
46	Gillis & Carrington mill site		
47	Tarantula quartz mine		18.56
48A&B	Gagnere quartz mine & mill site		12.44
49	Prospect quartz mine		20.65
50	Grand Turk quartz mine		20.00
51	Rising Sun quartz mine		20.65
52	Our Flag quartz mine		20.32
5574	Mexican & Spring Hill gold quartz mine		21.24
57	OK quartz mine		20.41
59	Combination quartz mine		1.99
60	North Extension of OK quartz mine		19.78
	Montreal Cons. gold quartz mine		39.885
61	Free Coinage loc.	8.901	
62	John Oenkey loc.	16.555	
63	Omega loc.	10.51	
64	Gold Bound loc.	3.919	
65	Gopher quartz mine		7.65
66	Soldier Gulch quartz mine		15.31
67	North Extension of Marryatt quartz mine		8.54
	Norwegian Cons. quartz mine		39.3464
68	Norwegian loc.	16.8434	
68A	Norwegian mill site	1.015	
69	Golden Rule loc.	12.2189	
69A	Golden Rule mill site	1.0969	
70	Spot Cash loc.	8.1722	
71	Magruder quartz mine		20.65
72	Chileno quartz mine		15.99
73	Wilson & Means quartz mine		13.37
PM-1	Boston placer mine		120.00
PM-2	Marble placer mine		40.00
PM-3	Experimental placer mine		30.00
PM-4	Reservoir placer mine		55.00
PM-5	Ball placer mine		150.00
PM-6	Elton placer mine		10.00
PM-7	Marble placer mine		120.00
PM-8	Tuolumne placer mine		130.00
PM-9	Black Hawk plumbago mine		60.00
PM-10	White Lead placer mine		10.00
PM-11	Ingolotti & Co. placer mine		10.00
PM-12	Three Pine Gulch placer mine		30.00
PM-13	Yankee Hill placer mine		10.00
PM-14	Yours Truly placer mine		20.00
PM-15	Nelson placer mine		20.00
PM-16	Wolf & Co. placer mine		20.00
PM-17	Santiago placer mine		30.00
PM-18	Alves placer mine		30.00
PM-19	Williamson placer mine		20.00
PM-20	Douglassville placer mine		100.00
PM-21	Blue Rock placer mine		60.00
PM-22	Davis placer mine		40.00
PM-23	Clark placer mine		20.00
PM-24	Davis placer mine		20.00
PM-25	Springfield placer mine		100.00
PM-26	Doyle placer mine		160.00
PM-27	Royal placer mine		70.00
PM-28	Jefferson placer mine		20.00
PM-29	Slip Up placer mine		20.00
PM-30	Crystal Spring gravel mine		50.00
PM-31	Shaws Flat gravel gold placer mine		50.00
PM-32	Raging Canal placer mine		30.00
PM-33	Browns Flat placer mine		130.00
PM-34	Eureka placer mine		100.00
PM-35	Squabble Town placer mine		10.00
PM-36	Trolese placer mine		20.00
PM-37	Smith hydraulic mine		20.00
PM-38	Hathaway placer mine		10.00
PM-39	Spring Hill placer mine		20.00
PM-40	Shaws Flat placer mine		40.00
PM-41	Harrington placer mine		20.00
PM-42	Haslam placer mine		30.00
PM-43	Brooks placer mine		20.00
PM-44	Buckeye placer mine		120.00
PM-45	Peppermint Falls placer mine		80.00
PM-46	Empire gravel mine		100.00
PM-47	Bed Rock Blue Gravel placer mine		40.00
3619A, B, C, D, E, F	Densmore Cons. quartz mine		59.43
3628	Thompson Hill gold quartz mine		19.118
3629	Shaw & Schollar (Street) quartz mine		20.13
3734	Mountain View quartz mine		35.40
3767	Lead & Tam O'Shanter quartz mine & mill site		36.14
3779	Ball quartz mine		20.66
3805	Gross Cons. quartz mine		19.63
3854	Santissima quartz mine		10.97
3858A	Gillis quartz mine		20.26
3987	Eustis placer, and Diamond, Ruby, Sapphire quartz mines		89.68
4012	Red Hill quartz mine		18.81
4224A&B	Good Luck quartz mine & mill site		2.59
4378	Marryatt quartz mine		5.22
4399A&B	Duchess Cons. quartz mine & mill site		89.97
4452	Toledo Cons. quartz mine		41.32
4460	Alta quartz mine		19.66
4494	Kohanoff, Good Hope quartz mine		13.99
4503	Austrian quartz mine		2.48
4993	Anti Chinese quartz mine		15.864
5002A&B	Wickham quartz mine & mill site		16.762
5015	Relief & Surplus quartz mine		16.616
5068	Justice Lode quartz mine		11.870
5028	Ferelli quartz mine		
5261	Buena Vista quartz mine		22.01
5277	Protector quartz mine		19.434
5544	Jackson Flat & Parallel quartz mine		27.323
5550A&B	Good Luck quartz mine & mill site		17.728
99	Mullins quartz mine		
5612	Little Leo quartz mine		13.765
5662A&B	Nut Pine quartz mine & mill site		9.721
5923	Lisonjera quartz mine		8.367
6132	National quartz mine		19.118
	T. 1 N., R. 14 E., M.D.		
37	Trio (Harvard) quartz mine		32.62
38	McCann quartz mine		3.28
39	Hitchcock gold quartz mine		9.38
40	Grey Eagle gold quartz mine		8.46
44	App quartz mine & mill site		25.43
45	Sweeney quartz mine & mill site		19.28
46A&B	Raw Hide No. 2 quartz mine & mill site		12.49
47	Alameda quartz mine		20.62
48	Paducah placer mine		107.55
49	Raw Hide placer mine		152.40
50	Mooney quartz mine & mill site		7.60
51	Omega Table Mountain gravel mine		160.00
52	Golden Rule quartz mine & mill site		38.40
53	Pino Blanco quartz mine		19.39
54A,B,C	Heslep quartz mine & mill site		18.33
55A&B	Dutch quartz mine & mill site		14.92
56	Tarantula quartz mine		18.56
57	Knox & Boyle quartz mine		24.76
58	Knox & Boyle quartz mine		
59	Mazeppa quartz mine		22.65
60A&B	Raw Hide quartz mine & mill site		15.81
62	Prospect quartz mine		20.65
63	Alabama Cons. quartz mine, Alabama loc.		20.65
64	Alabama Cons. quartz mine, Booker loc.		15.17
65	Alabama Cons. quartz mine & mill site		4.92
66	Shore quartz mine		14.82
67	Isabella & Gem Cons. quartz mine		20.04
68A&B	Miller & Holmes quartz mine		24.76
69	Table Mountain Alpha gravel mine		91.68
70	Juniper quartz mine		12.465
71A&B	Erin-Go-Bragh quartz mine		21.19
72	Pacific Gold quartz mine		3.71
74	Tiger placer mine		120.00
75	Rappahannock quartz mine		14.82
76	Golden Gate quartz mine		20.47
77	Golden Sulphuret quartz mine		16.23
78	New Era quartz mine		13.27
79A&B	Crystelline quartz mine & mill site		14.51
80	Cloudman quartz mine		10.02
81	Crystalline quartz mine No. Harris & Olive loc.		9.248
82	Crystalline quartz mine, Opal loc.		
83	Vulture quartz mine		11.11
84	No. One lode		10.04
85	Nyman Cons. quartz mine, loc. 1		7.26
86	Nyman Cons. quartz mine, loc. 2		
87	Sarah Francis quartz mine		19.97
88	Lucky Star gold & silver mine		15.93
89	Badger quartz mine		20.66
PM-1	Oarkle placer mine		20.00
PM-2	Blue Jacket placer mine		69.40
PM-3	Valponi placer mine		10.00
PM-4	Smith placer mine		160.00
PM-5	McKinley placer mine		120.00
PM-6	Punch Bowl placer mine		160.00
PM-7	Julian placer mine		20.00
PM-8	Montezuma placer mine		19.225
PM-9	Oak Shade placer mine		20.00
PM-10	Red Hill placer mine		40.00
PM-11	Hosig placer mine		120.00
PM-12	Hosig placer mine		60.00
PM-13	Rough & Ready placer mine		209.60
3568	Juniolta placer mine		4.37
3569	Mexican Flat placer mine		48.65
3644	Sobranto quartz mine		5.039
3651	Behlow, Fischer, & Behlow Ext. placer mine		42.197
3652A&B	Southorn Ext. Golden Sulphuret quartz mine		14.44
4111	Gerrymander Cons. quartz mine		30.18
5001	Chanteleau quartz mine		11.167
5747	Manzanita quartz mine		17.476
5876	Little Alabama quartz mine		4.93
6160	Rainbow quartz mine		20.234
5427	Mackoy quartz mine (see PM-8)		
	T. 1 S., R. 14 E., M.D.		
37A	Shawmut quartz mine		17.54
37B	Mamouth placer mine		15.14
38	Eagle quartz mine		23.75
39	Republican quartz mine		9.77
40	Orcutt quartz mine		17.61
41	Bella Union quartz mine		9.63
42	Lone Star quartz mine		19.97
43	Brown Bird quartz mine		20.775
44	Albion Cons. quartz mine, Great Eastern loc.		16.29
45	Albion Cons. quartz mine, Farrington loc.		5.11
46	Albion Cons. quartz mine, Delender loc.		18.17
47	Albion Cons. quartz mine, Bob loc.		8.40
48	Albion Cons. quartz mine, Hard Tack loc.		18.96
49	Homestake quartz mine		18.816
PM-1	Wovels Creek placer mine		66.89
PM-2	Gold Dredge placer mine		62.77
PM-3	D. E. Stratton placer mine		21.265
PM-4	D. E. Stratton placer mine		
PM-5	Tuttle placer mine		64.31
PM-6	D. E. Stratton placer mine		160.00
PM-7	Bird placer mine		10.72
PM-8	Moffitt Canyon placer mine		154.10
PM-9	Humfield & Mayers placer mine		80.00
3630	Shawmut placer mine		117.88
4317	Posenfeld Cons. quartz mine		44.86
4319	Hector quartz and placer mine		18.25
4320	Raymon quartz mine		1.37
4437	Nugget quartz mine		18.80
4482	Mountain View quartz mine		20.66
4534	Humfield & Mayers placer mine		24.61
4936	Tarantula Hawk quartz mine		7.683
4937	Golden Horseshoe & Boulder Deep quartz mine		40.161
5756	Lula, Jones, & Poor Sinner quartz mine		23.095
4821	Omega & Western Ext. quartz mine		
4822	Tarantula quartz mine		
11	Gray Eagle magnesite deposit		
12	White Rock magnesite deposit		
13	Peter Maki magnesite deposit		
14	Lucky Strike placer mine, N.P.		20.00
	T. 3 N., R. 15 E., M.D.		
37	Keltz (sec. 25) quartz mine & mill site		20.65
37	Hazel (sec. 36) quartz mine		10.32
38	Philadelphia placer mine		156.17
39	Contention quartz mine		18.07
40	Snell quartz mine		20.66
41	True Business quartz mine		20.66
42	Argentum Cons. quartz mine No. 1		28.79
43	Argentum Cons. quartz mine No. 2		
44	North Ext. Keltz quartz mine		20.49
45A	Kelvin gold quartz mine		19.92
45B	Kelvin gold mill site		
46	Star quartz mine		19.35
PM-1	Bailey Ranch placer mine		40.00
PM-2	American Camp placer mine		50.00
3833	Gray Eagle & Rival quartz mine		36.72
4463	Riverside Cons. quartz mine		17.56
4544	Amazon quartz mine		15.17
4657	Bourbon Cons. quartz mine		128.46
4658	Roosevelt quartz mine		18.17
5693A&B	Arthur D., J. T. Evans, Easterbrook, Jubilee, Purdie quartz mines, Easterbrook mill site (part of Hazel Dell mines)		68.775
13	Mountain Lily or Five Mile quartz mine		
14	Sonnot quartz mine		
15	Grant group quartz mine		
16	Gross quartz mine		12.5
	T. 2 N., R. 15 E., M.D.		
37	Hilton & McPherson placer mine		30.00
38	Shanghai quartz mine		10.34
39	Whoal Rough quartz mine		9.30
40	Whillo quartz mine		19.81
41	Old Smooth Bore quartz mine		20.69
42	Rifle quartz mine		20.69
43	Aetna quartz mine		5.47
44A	Wait quartz mine		18.676
44B	Wait mill site		
45A	Ham & Birney quartz mine		25.62
45B	Ham & Birney mill site		
46A	Hart & Jacobs quartz mine		25.65
46B	Hart & Jacobs mill site		
47	Scorpion quartz mine, N.P.		20.65
3567A&B	Black Oak group quartz mine		38.36
82	Hunter Fluming placer mine		105.75
187	Mohawk placer mine		30.00
195	Phoenix placer mine		20.00
196	Phoenix placer mine		20.00
201	Mailiyeau placer mine		20.00
211	Powhattan placer mine		40.00
215	Brown Geovanatle placer mine		60.00
254	Denton placer mine		40.00
560	Sullivan gravel mine		30.00
654	Old Home placer mine		40.00
691	Woolen placer mine		40.00
04279	Specimen Gulch placer mine		40.00
09693	Hard Gravel placer mine		20.00
09878	Gold Nugget placer mine		20.00
2577	Red Gravel placer mine		30.00
3694	Old Tuolumne Cons. quartz mine		89.13
4439	Sleveil Cons. quartz mine		41.32
5014	Sugarman & Nigger quartz mine		27.059
5277	Protector placer mine		19.434
5485	Self Ext. placer mine		19.285
5574	Mexican & Spring Hill placer mine		21.224
6090	Harvey Lode quartz mine		9.30
6200	Wind Wheel Lode quartz mine		20.435
5133	Bella Italia & Indiana Lode quartz mine, N.P.		18.176
5279	Bessie Lode quartz mine, N.P.		20.661
93	Alladena or Kearsarge quartz mine & mill site		80.00
92	Phoenix Lake granite quarry		
91	Belleview or Hyde quartz mine		
	T. 1 N., R. 15 E., M.D.		
37	Pine Nut quartz mine		20.66
3567	Live Oak quartz mine		9.81
3567A	Coria quartz mine		2.47
3567B	Live Oak mill site		4.58
3706	Cornucopia quartz mine		16.10
3844	Julian quartz mine		18.32
4113	New Edna quartz mine		15.96
4435	Edna No. 2 quartz mine		8.90
4436	Cornucopia No. 2 quartz mine		8.19
PM-1	Arroyo gravel mine		92.55
PM-2	Kincaid Flat placer mine		160.00
PM-3	Independent placer mine		40.00
7	Golden Gate Mines, Inc.		
8	Childress limestone		
9	Murphy Bros. limestone		
10	Musante limestone		
11	Mayhall limestone		
12	Dunning limestone		
13	McPherson limestone		
14	McCormick limestone		
15	U. S. Lime Products limestone		
16	Fitzgerald quartz mine		
	T. 1 S., R. 15 E., M.D.		
37	Kelley gold quartz mine		26.81
38A	Clio gold quartz mine		10.70
38B	Clio mill site		2.80
39	Willietta gold quartz mine		20.25
40	Republican		9.97
41	Black Warrior quartz mine, North Star loc.	20.66	55.92
42	Black Warrior quartz mine, Black Warrior loc.	11.45	
43	Black Warrior quartz mine, Yellow Jacket loc.	18.81	
44	Black Warrior mill site	5.00	
45A	Little Comstock quartz mine		20.657
45B	Little Comstock mill site, N.P.		4.997
3773	Paupers Dream quartz mine		19.25
3898	Side Hill quartz mine		13.76
3997A	Black Hawk quartz mine		25.66
3997B	Black Hawk mill site		
3998	Chance quartz mine		17.117
4043	Hughes quartz mine		37.31
4044	Oynola quartz mine		20.56
4112A&B	Rough & Ready quartz mine & mill site		25.60
4255A	Union quartz mine		10.88
4255B	Union mill site		
4528	Free Lance quartz mine		18.31
4529	Free Lance Ext. No. 4 quartz mine		17.51
4663	Side Hill mill site		4.66
4727	Mother Lode quartz mine		2.24
4989	Last Chance Free Gold, Charley Haley, & Wilbur quartz mine		58.538
5131	Criss Cross & Relief quartz mine		30.962
5301A&B	Big Chunk quartz mine		24.898
5416	Tiger & Buffalo quartz mine		33.686
5430	Traction quartz mine		2.086
5500	Sonora, M.B., & Hayes quartz mine		54.069
5543	Roosevelt & Buttercup Cons. placer mine		38.445
5635A&B	Buona Speanza & Josephine quartz mine & mill site		45.26
5734	Pet Cossey quartz mine		14.34
5810	Silken quartz mine		18.02
6093	Buck Horn & Back Bone quartz mine		18.41
6095	Mayflower quartz mine		9.67
PM-1	Bonanza placer mine		14.37
PM-2	Moffitt Canon placer mine		154.10
PM-3	K.S.S. placer mine		39.79
5558a	Sentinel quartz mine		128.702
5558b	Riverside		
5558c	Santa Rosa		
5558d	Blue Lead		
5558e	Ofer		
5558f	Fourth of July		
5558g	Moccasin		
3948	Blackfoot quartz mine		
4490	Gladstone quartz mine		18.38
46	Eureka quartz mine (unsurveyed), N. P.		
47	O'Albergaria quartz mine (unsurveyed), N.P.		
	T. 2 S., R. 15 E., M.D.		
37	Kelly placer mine		5.15
38A	Salambo copper mine (Washington), N.P.		
38B	Salambo mill site, N.P.		
39A	Little Comstock quartz mine		20.657
39B	Little Comstock mill site, N.P.		
4133	Golden Key Cons. quartz mine		94.68
	T. 3 N., R. 16 E., M.D.		
PM-1	Wild Rose placer mine		155.95
PM-2	Diamond placer mine		120.00
PM-3	Mountain placer mine		110.00
PM-4	Sugar Pine placer mine		50.00
PM-5	Last Chance placer mine		30.00
6	North Extension of Green quartz mine, N.P.		
7	Temescal quartz mine, N.P.		
	T. 2 N., R. 16 E., M.D.		
37	Confidence quartz mine		30.42
38	North Confidence quartz mine, N.P.		
39A	Uncle Sam quartz mine		7.07
39B	Uncle Sam mill site		
40	Soulsby quartz mine & mill site		28.41
41	Empire gold quartz mine, N.P.		
42	*Platt gold quartz mine*		*17.21*
43	Mt. Vernon quartz mine		20.69
44	Johnson & Bradbury quartz mine		8.69
45	Wheat Perran quartz mine		14.90
46	Excelsior quartz mine		15.70
47	Churchill quartz mine		14.41
48	Jessie quartz mine		20.69
49	Edith quartz mine		
50	Independence quartz mine		20.32
51	Prudhomme quartz mine		20.65
52	Cordove quartz mine		17.69
53	O.P. quartz mine		20.65
54	Lamphire quartz mine		20.54
55	Independence quartz mine		15.83
56	Sunny South quartz mine, N.P.		20.65
57	Mammon quartz mine, N.P.		19.39
58A	Gilson quartz mine		22.91
58B	Gilson mill site		
59	Carlotta Cons. quartz mine, Carlotta loc.		30.30
60	Carlotta Cons. quartz mine, Pennsylvania loc.		
PM-1	Andrew Scanavino placer mine		10.00
PM-2	Barrett placer mine		20.00
PM-3	Kibbe & Rowell placer mine		60.00
PM-4	Cherokee Gravel & Gold Mining Co. placer mine		212.21
PM-5	Laura placer mine		40.00
PM-6	J. F. Anderson placer mine		80.00
PM-7	Washington placer mine		50.00
PM-8	Hidden Treasure placer mine		125.68
3659A	Green Cons. quartz mine, Green loc.		32.71
3659B	Green Cons. quartz mine, Mt. Moriah loc.		
3701	Laura & North Star quartz mine		37.09
3740	Reward, April, & Madison quartz mine		35.41
3771	Wall Street & Sugar Pine quartz mine		36.29
4414	Iruinla Irene quartz mine, N.P.		
4440A	Parole quartz mine		18.84
4440B	Parole quartz mine		
4457	Joe Hooker & Wild Cat quartz mine		27.85
4583	Parallel & Mt. Bell quartz mine		31.96
5112	Central quartz mine		10.95
5533	Mountain, Mary, Little Gem, Mt. Provo quartz mine		54.896
5565	Electric & Thunderbolt quartz mine		31.50
5605	Hoot Mon, May, & Hawk quartz mine (formerly Phoenix Lake Gold Mining Co.)		53.908
5993	Fair Maiden quartz mine		12.123
61	Casa Madera quartz mine, N.P.		
62	Columbus quartz mine		
6165	Ryan Lode quartz mine		20.343
63	East Bell and Trilby quartz mines, N.P.		
	T. 1 N., R. 16 E., M.D.		
37	Pine Nut quartz mine		20.66
38	New Albany quartz mine		18.59
30	Eureke gold quartz mine		16.445
40	Cave Diggings placer mine		155.35
41A&B	Spring Gulch quartz mine & mill site		39.38
42A&B	Consuelo gold quartz mine & mill site (part of Providence)		14.39
43A&B	Buchanan quartz mine & mill site		24.69
44	Chaparral quartz mine		20.60
45	Bonita quartz mine		11.05
46	Summers quartz mine		23.20
47	Starr King quartz mine		24.40
47A	Starr King mill site No. 1		
47B	Starr King mill site No. 2		
48	Sherman quartz mine		25.62
48A	Sherman mill site		
49	Garfield quartz mine, N.P.		
50	Buchanan Ext. quartz mine		19.97
51A	Mary Ellen quartz mine		20.65
51B	Mary Ellen mill site		
52	Seminole quartz mine		20.65
53A	Grizzly quartz mine		14.81
53B	Grizzly mill site		
54	Worcester quartz mine		20.65
55	Somerset quartz mine		14.12
56	Gilson quartz mine & mill site		22.91
57	*New Albany North Ext. quartz mine*		*16.52*
58	*New Albany South Ext. quartz mine*		*14.796*
59	Porto Fino quartz mine		5.05
60	Carlotta gold quartz mine, Carlotta loc.		30.30
61	Carlotta gold quartz mine, Pennsylania loc.		
62	Josiah quartz mine		19.43
PM-1	Hidden Treasure placer mine		125.68
PM-2	Star placer mine		120.00
PM-3	Cuno placer mine		10.00
PM-4	Doxler Fluming placer mine		30.00
3725	Goldwin Cons. quartz mines (Philadelphia, Boston, Rhode Island)		52.92
3743	Park & Mason quartz mine		15.352
3781	Fair Play Cons. (part of Providence) quartz mine		24.049
3791A&B	Blue Jay Cons. quartz mine		28.43
4029	Lillian Cons. (Mohican) quartz mine		57.76
4185	Dead Horse Cons. quartz mine		12.06
4711	Golden West Cons. quartz mine		27.42
4714	Lady Washington quartz mine		9.84
4746	Seminole mill site		4.52
4902	North Star Cons. quartz mine		41.281
4903	La Preciosa quartz mine		19.397
4953	Triumph quartz mine		17.650
4954	Elk & Wedge quartz mine		25.945
5684	Rattlesnake quartz mine		12.671
5750	New Year quartz mine		19.229
4385	Consolidated Garfield-Virginia quartz mine		51.59
	T. 1 S., R. 16 E., M.D.		
37	Mack (Big Casino) quartz mine		8.86
38	Nonparell quartz mine, N.P.		
39	Noname quartz mine, N.P.		
40	Sargent placer mine		32.84
42	Consolidated Diamond & De Ferrari quartz mine, De Ferrari loc.		28.07
43	Consolidated Diamond & De Ferrari quartz mine, Diamond loc.		
44	Two Brothers Cons. quartz mine, Two Brothers loc.		24.85
45	Two Brothers Cons. quartz mine, Little Sister loc.		
PM-1	Muller placer mine		77.22
PM-2	Cons. Bell placer mine		120.00
3714	Four Oaks quartz mine		17.69
3768	Bourne quartz mine		14.71
3773	Paupers Dream quartz mine		19.25
4430	Contact quartz mine		18.46
4561	Guiseppe Raggio quartz mine		4.08
4562	Bicknell quartz mine		19.74
4605	Longfellow Cons. quartz mine		11.27
4737	Duleek Cons. quartz mine		61.56
4842	Gold Ship (inc. Mayflower) placer mine		594.213
5106	Big Oak Flat No. 1 quartz mine		15.492
5374	Robinson Lode quartz mine		12.734
5403	Phil O'Neil Lode quartz mine		18.159
5415	Cline & Jackson Lodes quartz mine		40.954
5549	Champion Lode quartz mine		20.036
5564	Mohrman Lode quartz mine		14.192
5620A&B	Cosmopolite & Violet quartz mine		39.296
5758	Rhode Island Lode quartz mine		11.002
4619	Mount Jefferson quartz mine, N.P.		18.92
46	Sampson Lode		
47	Gold Run Lode		
48	Red Jacket claim		
49	Quinn claim		
50	Good Luck claim		
51	Miracle claim		
52	Pipe Dream claim		
	T. 2 S., R. 16 E., M.D.		
43A	McAlpine quartz mine		18.72
43B	McAlpine mill site		
3602	Bower quartz mine		15.80
4133	Golden Key Cons. quartz mine		94.63
4430	Contact quartz mine		18.46
6031A	Fleming quartz mine		32.551
6031B	Intervenor quartz mine		

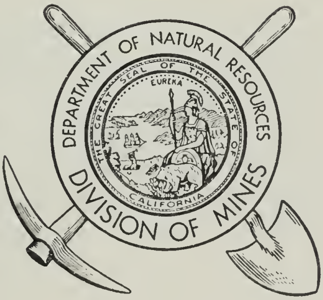
PHYSICAL
SCIENCES
LIBRARY

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

ol. 45 APRIL 1949 No. 2

CALIFORNIA JOURNAL OF MINES AND GEOLOGY



STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T HANNUM, Director

DIVISION OF MINES
OLAF P. JENKINS, Chief

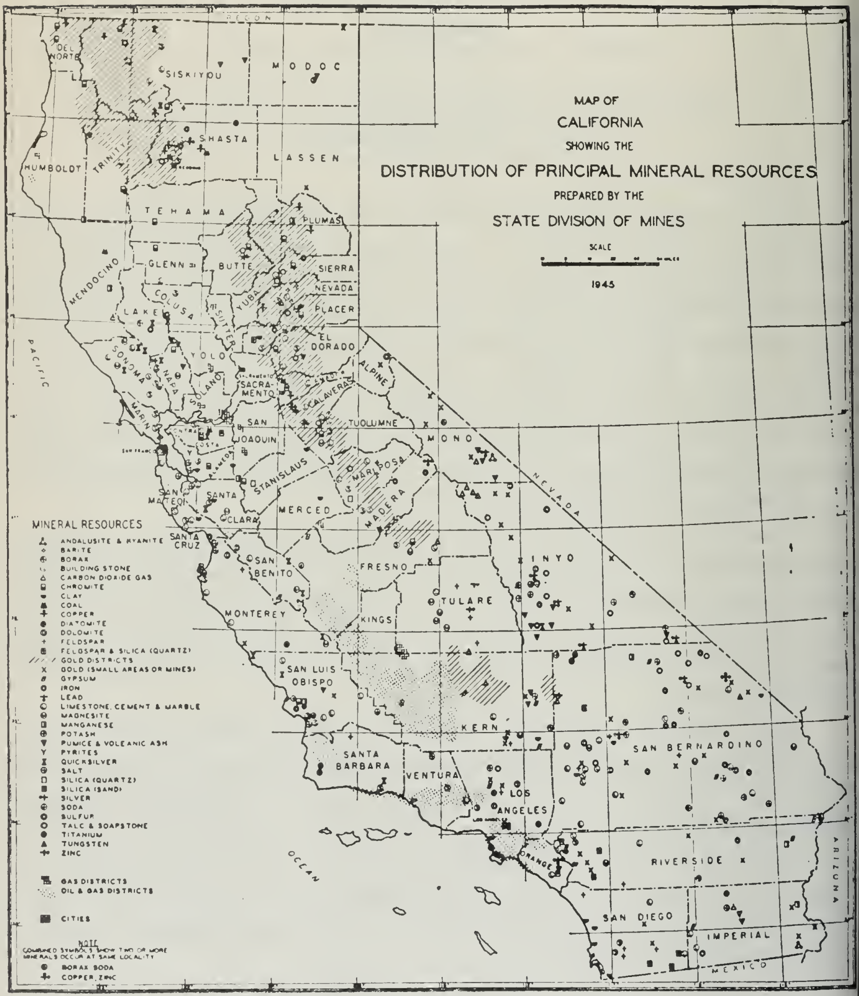
Headquarters
Third Floor, Ferry Building, San Francisco 11

District Offices
State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Box 445, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines are the quarterly **California Journal of Mines and Geology**, issued in January, April, July, and October of each year, and a series of **Bulletins. Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of publications will also be sent free upon request.


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES
SCALE
1945
OREGON
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
YUBA
COLUSA
SUTTER
PLACER
LAKE
EL DORADO
YOLO
SONOMA
NAPA
SOLANO
SACRAMENTO
ALPINE
AMADOR
CALAVERAS
MARIN
CONTRA COSTA
SAN JOAQUIN
TUOLUMNE
MONO
ALAMEDA
STANISLAUS
MARIPOSA
SAN MATEO
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
SAN BENITO
FRESNO
INYO
MONTEREY
KINGS
TULARE
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
PACIFIC
OCEAN
NEVADA
ARIZONA
MEXICO
MINERAL RESOURCES
ANDALUSITE & KYANITE
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY
BORAX SODA
COPPER, ZINC

CONTENTS

Page

Vater-Flooding as a Method of Increasing California Oil Production —Part 1, by Wilbur H. Somerton ____________________________ 123

Iineral Resources of Kern County, by W. B. Tucker, R. J. Sampson, and G. Oakeshott ____ 203

tate Geological Surveys, by Wilson M. Laird ______________________ 299

ndustrial Uses of Limestone and Dolomite, by Oliver Bowles and Nan C. Jensen ____ 319

n Act for the Development and Control of Atomic Energy ______ 335

ivision of Mines Publications Issued September 1, 1948 to February 15, 1949 ____ 357

PLATES

late 9. Opal pumice deposit, El Paso Mountains, Kern County __________ 220-221

10. H. M. Holloway, Inc., Kern County. *A*, Mining gypsum; *B*, Hauling gypsum ____ 220-221

11. Monolith Portland Cement Company, Kern County. *A*, Cement plant; *B*, Quarry ____ 220-221

12. *A*, Lost Hills oil field. *B*, Edison oil field ______________________ 220-221

13. *A*, Cudahy volcanic ash deposit, Kern County. *B*, High Peak tungsten mill, Kern County __________________________________ 220-221

14. Golden Queen mine, Kern County _____________________________ 220-221

15. Long Beach Salt Company, Kern County ______________________ 220-221

16. Pacific Coast Borax Company, Kern County ___________________ 220-221

17. Map showing mines and mineral deposits in Kern County ________In pocket

18. Oil fields of western Kern County ___________________________In pocket

WATER-FLOODING AS A METHOD OF INCREASING CALIFORNIA OIL PRODUCTION*

By Wilbur H. Somerton

OUTLINE OF REPORT

Page
- oreword, by Lester C. Uren 124
- ntroduction 125
- art 1—Factors influencing the application of water-flooding 129
  - Geological conditions 129
    - Structure 129
    - Stratigraphy 129
    - California conditions 131
  - Influence of mineralogical characteristics 132
    - Mineral content of reservoir sandstones 133
    - Mineral grain surface forces 135
    - Clays in reservoir sands 138
    - Cementing materials 142
    - Summary and correlation to California conditions 143
  - Physical properties of the porous medium 144
    - Texture and pore pattern 144
    - Porosity 147
    - Permeability 147
    - Summary and relation to California conditions 151
  - Distribution and nature of fluids 151
    - Modes of occurrence 151
    - Oil phase 152
    - Water phases 155
      - Connate water 155
      - Injection water 156
      - Water treatment 157
    - Correlation to California conditions 162
  - Fluid saturation 162
    - Saturation from core analysis 163
    - Fluid saturation by restored-state method 165
    - Saturation from electrical logs 166
    - Calculations of total and recoverable oil 167
    - Influence of saturation on flow and recovery characteristics 168
    - Summary and correlation to California conditions 170
  - Capillary and surface effects 171
    - Static conditions 171
    - Dynamic aspects 173
    - Importance to water-flooding 174
  - Principles of fluid displacement 174
    - Displacement from sand bodies 175
    - Displacement from individual pores 176
    - Summary 177
  - Principles of fluid flow 177
    - Mathematical analysis 177
    - Model studies 179
    - Summary 182
  - Injection rates and pressures 182
    - Injection pressures 182
    - Injection rates 184
    - Summary 187
  - Well spacing, completion, and behavior 187
    - Flooding patterns 188
    - Well spacing 189
    - The use of old wells 191
    - Delayed drilling 192
    - Well completion and reconditioning 192
    - Behavior of injection wells 193

---

* Thesis submitted in partial satisfaction of the requirements for the degree of troleum Engineer in the Graduate Division of the University of California. Manuript submitted for publication September 2, 1948.

Economics of water-flooding 195
- Costs as compared to primary production 195
- Physical factors 197
- Price, supply, and demand 198
- Other factors 199
- Summary 199

Bibliography 200

FOREWORD

In 1917, J. O. Lewis published his classic U. S. Bureau of Mines Bulletin 148 on *Methods of Increasing the Recovery of Oil from Wells.* That part of this publication which is devoted to a description of water-flooding techniques in the Bradford field of Pennsylvania was the first authoritative explanation of a method of oil production that was destined to play an important role in improving oil recovery efficiency. Since that time, many millions of barrels of petroleum have been recovered by water-flooding, and hundreds of professional papers by many technologists have contributed valuable information on this subject. Some have reported the results of laboratory studies, some have been concerned with field applications. The principles and theory underlying the displacement of oil from reservoir rocks by water have been discussed by several outstanding authorities.

Many of our larger oil companies, universities, the federal and several state governments have supported extensive research programs having for their objective the improvement of water-flooding techniques. Professional societies, industrial institutes, and government agencies have appointed secondary recovery committees that have given prolonged study, conducted symposiums and published reports of their findings.

From time to time it is advantageous to take stock of progress in a developing art: to piece together the many bits of information from various sources, to reconcile the differences in viewpoint that appear, to interpret the trends and to chart the course that promises further progress. Professor Somerton's monograph on *Water Flooding as a Method of Increasing California Oil Production* is of this character. The student of secondary recovery technology will find in the following pages an excellent summary of the literature of water-flooding, written in a style that will be clear to the novice, yet informative in the detail and wealth of material that it affords to the advanced technologist. The writer believes Professor Somerton's interpretations to be sound, his presentation well balanced and his conclusions dependable. They should be helpful in assisting students and research workers to gain a perspective of this important phase of petroleum technology.

Perhaps the most valuable contribution is found in that part of the paper in which an effort is made to apply the principles of water-flooding under the conditions presented in the California fields. These fields probably contain as much as fifteen billion barrels of residual petroleum not producible by present commonly used methods of primary recovery Undoubtedly a large part of this reserve in present known California fields will be found recoverable by improved methods of secondary recovery. Probably in many cases the water-flooding method will be applicable under suitable controls. Yet, comparatively little scientific effort has been directed toward a study of the peculiar conditions presented in the California fields and their probable influence on the efficiency of water-flooding as a means of securing a second crop of much needed oil. Professor Somerton's emphasis on this phase promises to be particularly helpful in delineating the research problems that must yet receive scientific study before the water-flooding techniques may be applied with confidence in the California petroleum industry.

LESTER C. UREN

Berkeley, California
October 24, 1948

INTRODUCTION

The United States has been favorably endowed by nature with tremendous resources of petroleum, of which California has had a large share. This seemingly unlimited supply of petroleum has been exploited for so long that it is difficult for most people to conceive of a shortage. Perhaps it is just this attitude which has occasioned the present predicament; for assuming an unlimited supply of any natural resource invariably leads to waste of that resource.

It has been stated periodically in past years that the petroleum resources of this nation were being depleted. In the past, however, shortages have been alleviated by discoveries of new flush fields, which raised the proven reserves to higher and higher levels. Such occurrences may leave the unimaginative with the feeling that each cry of shortage is but a false alarm. Nothing could be farther from the truth, however, for each time a shortage occurred in the past, every effort had to be made to bolster the petroleum reserves. Each new field or zone discovered meant one less to be discovered in the future. As all theories of the origin of petroleum agree that the natural process of formation requires nearly infinite time as compared to the life span of mankind, petroleum is an exhaustible resource.

The forces provided by nature for the recovery of petroleum from beneath the earth's surface have made it possible to obtain tremendous amounts of oil and gas with comparatively little effort. For this reason, the production of petroleum has never been a scientific or even a well-engineered process. These natural forces have been relied upon to such an extent that we now find ourselves unprepared to apply scientific methods. This problem is now well recognized and some advances have been made toward its solution in the past few years. A large amount of research is under way at the present time in an attempt to place petroleum engineering on as high a scientific level as many other engineering professions.

The two principal forces which cause the expulsion of petroleum from reservoir rocks into the well-bore are: (1) the expansion of gas commonly associated at high pressure with oil, either in a dissolved or free state; and (2) the pressure exerted by encroaching edgewater. Expanding gas, seeking the low-pressure area created adjacent to the well-bore, forces ahead of it, or carries with it, oil from the reservoir. In the early life of a new high-pressure field, the force is sufficient to lift oil from the bottom of the hole to the surface. This type of expulsion is highly inefficient, especially if the pressure differential between the reservoir and the well-bore is great. If not properly controlled, the force is rapidly dissipated, removing but a small portion of the oil in the reservoir. Edgewater under high pressure acts in a similar manner in displacing oil and forcing it to the low-pressure area about the well-bore. Hydraulic energy is not as readily dissipated as gas energy, and generally it is more efficient and recovers a larger percentage of the oil.

It has been estimated that past wasteful methods of production left as much as 75 percent of the original oil in the ground, unrecoverable by ordinary primary production methods. Secondary recovery methods have been developed to recover a portion of this oil. This is accomplished by applying artificial gas or water drive to depleted oil reservoirs, or by augmenting nature's forces in semi-depleted reservoirs. Secondary recovery offers certain advantages over primary production: (1) the type and nature of the substance causing expulsion of petroleum from the reservoir sand can be selected; (2) the rate at which the expulsive force is applied can be regulated; and (3) there is some degree of control as to where the expulsive force will be applied. Motion of fluids through the reservoir cannot be directly guided, but it can be influenced by the abovementioned controls. As more is learned about the principles of flow through porous media and reservoir behavior, motion of fluids through the reservoir can be guided more efficiently by control at the surface.

During the primary period of production operating expenses are at a minimum. At the worst, it is only necessary to lift the oil to the surface after natural forces cause expulsion into the well-bore. As nature's forces are expended, operating costs per barrel of oil recovered reach a maximum because of the progressively decreasing number of barrels produced. Thus the well or field reaches economic exhaustion when but a fraction of the original oil has been recovered. If, however, the rate of production can be increased by secondary recovery methods, total operating costs can also be increased, and a profit can still be realized.

It is most desirable to apply secondary recovery methods to fields in which the residual oil content is high. This is obvious from the standpoint of the total amount of oil available for recovery, but it is also important in the concepts of relative saturations and relative permeabilities which control the flow of fluids in the reservoir. Many of the older fields, principally those in which the chief expulsive force was the expansion of gas under pressure and in which wasteful methods of production were practiced, meet this requirement.

This report is to be primarily concerned with the water-flooding method of secondary recovery, for studies have shown that a greater recovery of oil can be usually realized from its application. Under favorable conditions, at least as much oil as was recovered by primary methods can be recovered subsequently by water-flooding. If this method could be applied successfully to all or most of the depleted or near-depleted oil fields, potential oil reserves would be greatly increased. Unfortunately, water-flooding technique has not been developed to the point where the process can be applied to all oil fields, but is restricted to a few fields where conditions are ideal or nearly so. Thus, a large field of research is open to determine which fields might be successfully water-flooded and to learn more about the principles of water-flooding so that they can be applied to other fields.

The California petroleum reserves situation has become serious in recent years. The reserves to production ratio has been dropping steadily since 1941, and no improvement is in sight. The heavy drain on California's crude oil reserves occasioned by the demands of the Pacific war, dealt a hard blow from which the state may never recover. Since the end of the war, the rapid growth of the state and its steady industrial expansion have made the situation even more acute. California has produced more than one-seventh of the total world production of oil to date but it is now having a difficult time in finding sufficient new reserves to keep pace with its increased rate of consumption. It has been estimated [1] that California has a residual oil reserve in excess of 26.6 billion barrels of "unavailable" oil in its depleted or near-depleted oil fields. This represents four times our cumulative production to date. Ultimately, the California oil industry will find it necessary to resort to secondary recovery to satisfy the growing demand for its products.

Secondary recovery is not new to California. A report of the California District Topical Committee of the American Petroleum Institute on production technology, presented by Van Wingen,[2] points out that there are past and current secondary recovery or gas or oil storage operations in 28 California fields. In nine of these fields operations are still in progress; in addition, there are eight primary pressure-control projects operating at the present time. In most cases, however, these have been small, half-hearted attempts that neither proved nor disproved the feasibility of secondary recovery.

Water-flooding projects have been very limited. The most notable is that in the Chapman zone of the Richfield field. Although experimental in nature, some interesting results have been obtained which will be presented in a later section of this paper. A similar project is under way in the Dominguez field. In the southeast portion of the Lost Hills field, a deep, high-pressure water zone has been admitted to the production zone through an edge well. This, in effect, will add to the natural expulsive force. In the Greeley field, a problem of waste-water disposal developed, giving rise to a process of reinjecting the produced water into the productive zone. The 3-year records of this project, although not conclusive, have indicated the feasibility of primary pressure control by the injection of water.

Although all of the above projects have been small scale and have not been in operation a sufficient length of time to prove their worthiness, they all seem to indicate that water-flooding has a fair chance of success in California. There are many favorable factors. The price of crude oil is the highest in recent history and it is the consensus that this higher price structure will be permanent in the petroleum industry. There is a definite shortage of oil in California which shows indications of being permanent. The costs of finding new oil reserves, of developing deep zones and fields in inaccessible regions, of producing from these deep zones and inaccessible regions, of transportation, etc., have all risen and will soon, if they have not already done so, overbalance the cost of secondary recovery.

There are many other problems of a physical and practical nature which must be considered in water-flooding. California fields present unique problems not encountered in other areas where water-flooding has been successful. Van Wingen [3] summarizes these problems as follows:

---

[1] Andrus, D. T., Secondary recovery research: Interstate Oil Compact Quarterly Bull., vol. 5, no. 2, pp. 16-26, August 1946.

[2] Van Wingen, N., and Johnston, N., Current concepts of secondary recovery: Am. Petroleum Inst., Drilling and Production Practice, pp. 196-208, 1946.

[3] Op. cit.

1. Sand thickness: large in California in comparison to other regions, making the control of the flow of fluids more difficult.
2. Sand permeability: low to medium, reducing the ease of flow of fluids.
3. Permeability uniformity: poor, resulting in erratic motion of fluids with bypassing probable.
4. Sand porosity: medium to high; since porosity is a measure of the fluid storage capacity, this may be a point in favor of California fields.
5. Oil gravity: low; hence the lower value of California crude.
6. Oil viscosity: medium to high; thus the oil is more difficult to recover.
7. Pool depths: medium to deep, increasing operating costs.
8. Drilling costs: high; a reflection of the greater depths.

Most of the above conditions would appear to be adverse; yet, Van Wingen [4] makes the following statement:

> "It is difficult to foretell to what extent a reservoir may depart from the optimum conditions—and yet be considered a likely prospect for an economically successful secondary recovery project as certain adverse conditions may under special circumstances be mutually compensatory. Thus, it is manifestly impossible to tabulate a single set of reservoir properties of such a critical nature that the failure of any one property of a given reservoir to measure up to these minimum requirements will cause a project to be non-commercial where secondary recovery is concerned. Instead, each physical property must be considered in the light of all the others. For example, the oil viscosity may be prohibitively high, but the sand characteristics, permeability, thickness, dip, and residual oil saturation may be sufficiently favorable to make the pool a likely commercial prospect in spite of the high viscosity."

These remarks define fairly well the present problem, and indicate the need for a critical review of the many factors involved in flooding.

---

[4] Op. cit., p. 205.

PART 1*

FACTORS INFLUENCING THE APPLICATION OF WATER-FLOODING

Geological Conditions·

Structure

The great diversity in the structural types of oil reservoirs makes it difficult to set up any but a very general classification system. This general system must be based on idealized structural types. Thus, if a given reservoir is said to be an anticline, it implies only that the anticlinal structure is the predominating feature.

Water-flooding can be applied to any type of structure, whether it be an anticline, monocline, fault trap, lenticular deposit, shoe-string sand, salt dome, or any one of a host of other types and modifications of types. It is important that the field be well defined structurally before considering water-flooding. The structure must be well closed by one means or another to prevent the migration of fluids to areas from which they cannot be recovered. Most water-flooding to date has been conducted in low-dipping structures, making it possible to flood in any desired direction or pattern without concern for gravity segregation. There is no reason why steeply dipping reservoirs cannot be flooded effectively if water is injected through down-dip wells, thus taking advantage of gravity segregation in maintaining uniform flood-water advance.

Continuity of reservoir formations is a geological characteristic of great importance to water-flooding. For example, any type of structure intersected and displaced by faults is not likely to lend itself well to water-flooding. This does not mean that any reservoir which is faulted should not be considered for water-flooding. However, much more information must be available in faulted than in non-faulted fields. If a field is faulted into isolated blocks of reasonable size and the fault zones are such that they will not permit the migration and loss of oil or injection water, it should be possible to water-flood such structures with little difficulty if other factors are favorable.

Stratigraphy

Uniformity of reservoir sands is important in that it enables water encroachment or flooding to be more readily controlled. Highly permeable streaks will inevitably lead to bypassing unless proper precautions are taken. On the other hand, it is probable that non-uniformity of the sands has resulted in a greater amount of the original oil being retained in the sand as bypassed oil, perhaps available for secondary recovery. Some authorities [5] rank the degree of uniformity of the sand second only to the amount of residual oil in importance in secondary recovery.

The depths and thicknesses of producing formations are also of importance in water-flooding. Great depths lead to economic difficulties, for it becomes impractical to drill new wells because of their prohibitive cost. Necessary remedial work on old wells in deep fields is also costly. Thus, as many water in-put and oil-producing wells as desired may not be available, and it is probable that the spacing of existing wells would not lend itself to the most efficient drainage pattern. There is some lower limit, depending on other factors, below which it would be impractical

---

* Parts 2 and 3 of this paper will be published in subsequent issues of the *California Journal of Mines and Geology.*

[5] Fettke, R. C., Dickey, P. A., and Torrey, P. D., Geological factors influencing secondary recovery: Am. Petroleum Inst. Prod. Bull. 232, pp. 151-154, 1943.

Table 1. Types of oil accumulation in California *

Type	Field
1. Normal closed anticline	1. Kettleman Hills North Dome
	2. Kettleman Hills Middle Dome
	3. North Belridge
	4. Ten Section
	5. Rio Bravo
	6. Wheeler Ridge
	7. Elwood
	8. Ventura Avenue
	9. Dominguez
	10. Santa Fe Springs
	11. West Coyote
	12. Seal Beach
2. Anticline—secondary control by faulting	1. South Mountain
	2. Inglewood
	3. Dominguez
	4. Long Beach
	5. Orcutt
	6. McKittrick
	7. Huntington Beach
	8. Wilmington
	9. Richfield
3. Anticlines—secondary control by unconformity	1. Elk Hills
	2. Buena Vista Hills
	3. North Belridge
	4. Belridge
	5. Playa del Rey
4. Sand lens on plunging anticline	1. Coalinga Eastside (Eocene)
5. Unconformity	1. Coalinga Westside
	2. Midway-Sunset
	3. Santa Maria Valley
	4. Edison
6. Fault accumulations	1. Mt. Poso
	2. Round Mountain
	3. Mountain View
	4. Whittier
	5. Brea-Olinda

---

* Reed, R. D., Position of California oil fields as related to geologic structure: California Div. Mines Bull. 118, p. 97, 1943.

to undertake a water-flooding project. Likewise, there is a minimum practical depth, for the maximum pressure that can be applied in water-flooding depends on the depth of the reservoir. In the northern Appalachian area it has been noted that if injection pressures exceed the static pressure of the column of rock overlying the oil sand, the water will cause fissures to open sufficiently to permit its escape. It has been found that in reservoirs less than 200 to 300 feet in depth, joints and fractured zones may be present which will permit the flooding water to break through to the surface.[6]

Thicknesses of productive formations probably have a bearing on water-flooding efficiency for it is generally conceded that it is easier to control the movement of fluids in relatively thin formations. Van Wingen [7] states that an optimum thickness is perhaps between 50 and 200 feet. He states further that the zone should be thick enough to assure an adequate reserve, yet thin enough to allow flooding as a blanket. It is difficult to consider the influence of strata thickness without considering the degree of uniformity of the sands. Greater thicknesses of the productive formations increase the probability of vertical variations in permeability which will result in the difficulty of controlling flow. Perhaps this, more than any other factor, determines the influence of strata thickness on water-flooding.

California Conditions

How do the geologic conditions common to California fields fit into the picture? It is interesting to note the classification of California fields according to structural types in table 1. Of the 36 important fields included in the survey, 12, or one-third, are normal closed anticlines in which faulting and unconformities are of minor importance. Nine of the fields are anticlines in which faulting is an important secondary control. Five fields are anticlines with unconformities as important secondary control. One field, the Coalinga Eastside, is a stratigraphic trap on a plunging anticline. There are four fields where the accumulations are due to unconformities in which the type of fold is incidental. The remaining five fields are classed as fault accumulations. Needless to say, this classification is only approximate because of the lack of geologic data on the older fields. Nevertheless, it indicates the great diversity of structural types common to California. As a result, no general statement or conclusion can be made as to the feasibility of water-flooding in California on the basis of geologic structure alone. Rather, each field must be analyzed separately to determine its merits or demerits from this standpoint. It is interesting to note, however, that the majority of the fields are anticlinal in nature and in many cases dips may be excessive for blanket flooding.

California reservoir sands show a general lack of uniformity. Great thicknesses of productive sands with pronounced vertical and even lateral variations in permeability and porosity are common and even characteristic. This means that more oil is retained in the reservoirs because of the decrease in primary recovery efficiency. On the other hand, it will be more difficult to control the movement of fluids in water-flooding operations. From this standpoint, the success of water-flooding in California will depend to a large degree upon the ability of operators to gain complete knowledge of sand variations throughout the areas to be flooded. With this information available, it may be possible to apply methods of selectively sealing thief sands and controlling injection in other sands according to their permeabilities. The effects of lateral permeability variations can be partially overcome by close well spacing.

---

[6] Fettke, R. C., Dickey, P. A., and Torrey, P. D., op. cit.

[7] Op. cit.

The last geologic factor of importance to be correlated with California conditions is that of the depth of productive formations. In general, productive horizons in California are medium to deep. This is true especially of the newer fields and the recently discovered deep zones in older fields. However, the older fields in California and consequently the most interesting ones from a standpoint of water-flooding, should be more correctly classed as shallow to medium. For example, the Oil City field zones vary from 300 to 1700 feet; the McKittrick shallow zones from 870 to 1615 feet; and the Midway Sunset zones from 500 to 3000 feet in depth. Overdrilling, townlot drilling, and general waste were prevalent in the early industry in California; and because of these highly inefficient recovery practices, a large amount of residual oil may still be expected in the formation. In the closely drilled deeper fields, enough wells may be available for injection and production so that new wells would be unnecessary. Such wells would undoubtedly require a certain amount of remedial work, but in the long run, costs should not be prohibitive.

Influence of Mineralogical Characteristics

The mineralogical characteristics of the reservoir sands undoubtedly have a pronounced influence on water-flooding efficiency. This is one of the most neglected phases in the study of petroleum reservoirs. A great volume of literature is available on the mechanics of flow through porous media. Much has been written on the nature, characteristics, and behavior of the fluids flowing through the porous medium and on some of the properties of the medium itself, such as porosity and permeability. Yet, only limited information is available regarding the influence of the mineralogical composition of the sands, their texture, and cementation. It should be mentioned at this point that the following discussion will be limited to sandstone reservoirs. Limestone reservoirs would undoubtedly present many new and interesting problems but this type of reservoir is not common in California.

Most petroleum reservoirs, being made up of fine-sized sand grains, present an enormous surface area per unit volume of sand. A large part of the unrecoverable oil in a reservoir results from the retention of thin films of oil on the sand-grain surfaces; therefore, if this film of oil can be removed during water-flooding, ultimate recovery will be increased. As the openings between sand grains are capillary in size, surface forces become important in the study of displacement and flow through the sand. These surface forces are functions of the physical properties of the mineral surface (wettability and absorption) which are different for each type of mineral.

The presence of clays, especially those types with a high swelling and base exchange capacity, even in small quantities, may alter and completely control physical characteristics of the reservoir rock.

The size, shape, roundness, sorting, and distribution of the sand grains determine the texture of the medium and the size, shape, and distribution of the pores. These factors have a dominant influence on porosity and permeability. Important also in this respect is the cementation of the sands. The cementing material, whether it be silica, carbonate, or clay, will serve both to modify the size and shape of the pores and to mask the surface effect of many of the sand grains. The chemical properties of the sand grains are of additional importance from the standpoint of the ease with which they dissolve in the fluids with which they may be in contact.[8]

Mineral Content of Reservoir Sandstones

Sedimentary rocks are made up in general of fragments and alteration products of igneous, metamorphic, and older sedimentary rocks. The final mineral composition of the sedimentary rock depends, to a large extent, upon the composition of the source material. Also important in this respect is the nature of the decomposition and disintegration forces which were active on the original material. The mode and distance of transportation and the conditions of deposition influence the mineral content as well as the physical nature of the mineral grains.

The processes of disintegration and decomposition of rock masses need not be discussed here. Tyrrell [9] has explained the action of these processes on granite as shown in table 2.

Although subsequent intrastratal solution may promote further decomposition, this analysis gives a clue to the minerals which might be expected in a sedimentary rock. Table 3 gives a modification of Tickell's classification of the frequency of occurrence of minerals in sedimentary rocks. It is possible for a great number of minerals to occur in any given sedimentary formation. For the most part, however, only a few of the more resistant of the above minerals occur in any appreciable quantity. Quartz is the most abundant sedimentary rock forming mineral. It is followed in importance by the feldspars, calcite, hornblende, and mica.[10] With the exception of the clay minerals, the presence in small quantities of other minerals would have no appreciable effect on surface forces. However, the presence of clay even in small quantities may exert such an important influence as to actually control surface forces.

It is difficult to classify sandstones into types on the basis of their mineral content alone because of the great variations commonly found. The following tentative classification [11] is based primarily upon the conditions existing at the time of sedimentation, but characteristic mineral assemblages are common to each type.

1. *Quartzose.* Material is deposited on broad, flat, continental shelves during periods of orogenic quiescence; displays a high degree of sorting and uniformity as to size, shape, and composition. Only the most stable minerals such as quartz, tourmaline, zircon, etc. are present and they are often well cemented with carbonates or silica. Interbedding of limestones is very common.
2. *Graywacke.* Material is deposited during periods of moderate deformation in deeper sedimentary basins; more poorly sorted; mechanical disintegration and chemical decay restricted. Minerals present include angular grains of the stable minerals, fine mica flakes, non-decayed rock fragments, illite and kaolinite clays. Cementation may be somewhat limited, as may the presence of limestone interbedding.

---

[8] Krynine, P. D., Mineralogy of water flooding: Prod. Monthly, vol. 3, no. 2, p. 10, 1938.

[9] Tyrrell, G. W., The principles of petrology, New York, E. P. Dutton & Co., 1929.

[10] Uren, Lester C., Petroleum production engineering, vol. II, Exploitation, New York, McGraw-Hill, 1939.

[11] Krynine, P. D., op. cit.

*Table 2. Disintegration and decomposition of granite.**

ORIGINAL MINERAL		REACTION	PRODUCT
Quartz	SiO_2	Remains undecomposed	Sand grains.
Orthoclase	K_2O	Goes into solution as carbonate, chloride, etc.	Soluble material.
	Al_2O_3 $6SiO_2$	Hydrated and combined to form hydrous aluminum silicate	Clay.
		with the liberation of soluble silica	Soluble material.
	$3Na_2O$	Goes into solution as carbonate, chloride, etc.	Soluble material.
Oligoclase	CaO	Forms carbonate, which is soluble in water containing carbon dioxide	Soluble material.
	$4Al_2O_3$ $20SiO_2$	Decomposes as in orthoclase	Clay.
Muscovite	$2H_2O$ K_2O $3Al_2O_3$ $6SiO_2$	Remains undecomposed	Mica flakes.
Biotite	H_2O		Water.
	K_2O	Goes into solution as carbonate or chloride	Soluble material.
	$2(Mg,Fe)O$	Goes into solution as carbonate or chloride; iron carbonate oxidizes to hematite or limonite	Soluble material and coloring matter.
	Al_2O_3	Forms hydrous aluminum silicate	Clay.
	$3SiO_2$	and soluble silica	Soluble material.
Zircon	ZrO_2, SiO_2	Remains unaltered	Zircon grains and crystals.
Apatite	$Ca_3(PO_4)_2$ (F,Cl)	Is soluble	Soluble material (?).

---

* From Tyrrell, G. W., The principles of petrology, 2d ed., pp. 173-174, New York, E. P. Dutton & Co., Inc., 1929.

3. *Arkose.* Material deposited rapidly during intensive diastrophism; very poorly sorted, practically no chemical decay. Deposits are thick and heterogeneous; have high content of unstable minerals such as feldspars and hematite, and little cementation, except by clays. Kaolinite clay is common but montmorillonite may also occur in large proportions. Highly oxidized, landlaid deposits are often interbedded.

Mineral Grain Surface Forces

Adhesive retention is the result of an intermolecular attraction existing between liquids and sand-grain surfaces. In an oil reservoir each sand grain becomes covered with a film of liquid, either oil or water, which is tightly retained by these molecular forces. In addition to this surface film, pressure and capillary forces are probably sufficient to draw liquid into minute fractures and cleavage planes and, in some cases, within the loose crystalline structure of the mineral grain itself.[12] The surface film is of the greatest importance from the standpoint of the amount of oil that may be retained by adhesion.

Early work by Uren and El Difrawi [13] has shown that one cubic foot of 48-mesh sand (assuming each grain to be spherical) presents 4,300 square feet of surface; one cubic foot of 200-mesh sand presents 17,000 square feet of surface. The tremendous surface areas presented by natural sandstones make adhesive retention a very important consideration. In experiments with various crude oils, film thicknesses were estimated to be a minimum of from 0.002 of a millimeter to 0.006 of a millimeter.[14] Thus, the minimum amount of oil retained in a cubic yard of 100-mesh sand would be about 0.38 barrel. It is generally thought that a considerably greater film thickness would be found in actual reservoirs.

Although this work gave an indication of the magnitude of adhesive retention, it did not satisfactorily relate the phenomenon to reservoir conditions. Water is known to be present in all or at least most of our oil reservoirs. What then would be its influence on oil retention? To explain more satisfactorily the nature of these surface forces and to determine the variations of their effectiveness on different minerals, Bartell and co-workers [15] have devoted much time and effort. Fundamentally, these forces consist of the following: surface tension, interfacial tension, and the opposing force called ''adhesion tension''. Surface tension of a liquid is a manifestation of the attraction between molecules near the surface where the molecules are subjected to an unbalanced force. As a result, the inner molecules exert an inwardly directed force on the surface molecules, tending to adjust the unbalance and giving a minimum surface area.[16] Surface tension is measured as the force necessary to overcome this surface attraction and in measurable terms is defined as the force exerted on a straight line of unit length in the surface, in a direction parallel to the surface but perpendicular to the line. This is expressed in dynes per centimeter.[17] Interfacial tension,

---

[12] Uren, Lester C., op. cit.

[13] Uren, Lester C., and Fahmy, E. H., Factors influencing the recovery of petroleum from unconsolidated sands by waterflooding: Am. Inst. Min. Met. Eng. Trans., vol. 77, p. 318, 1927.

[14] Uren, L. C., and Fahmy, E. H., op. cit.

[15] Benner, F. C., Dodd, C. G., and Bartell, F. E., Evaluation of effective displacement pressure for petroleum oil-water-silica systems: Am. Petroleum Inst. Drilling and Production Practice, p. 169, 1942.

[16] Getman, F. H., and Daniels, F., Outlines of theoretical chemistry, 6th ed., New York, John Wiley & Sons, 1940.

[17] Benner, F. C., Riches, W. W., and Bartell, F. E., Nature and importance of surface forces in production of petroleum: Am. Petroleum Inst. Drilling and Production Practice, pp. 442-448, 1938.

Table 3. Frequency of occurrence of minerals in sedimentary rocks.†

Very common	Common	Rare
*Biotite	Actinolite	Anatase
*Calcite	Andalusite	Apatite
Chlorite	Augite	Aragonite
Garnet	Cassiterite	Barite
Hornblende	Chromite	Basaltic hornblende
Ilmenite	Corundum	Brookite
*Kaolinite-type clay	Enstatite	Diopside
Leucoxene	Epidote	Dumortierite
Limonite	Glaucophane	Fluorite
Magnetite	Gypsum	Galena
Montmorillonite-type clay	Hypersthene	Glauconite
	Kyanite	Hematite
Muscovite	Microcline	Sillimanite
**Orthoclase	Monazite	Sphalerite
**Plagioclase	Pargasite	Spinel
Pyrite	Rutile	Spodumene
**Quartz	Staurolite	Vesuvianite
Rock fragments	Titanite	Xenotime
Chert	Topaz	Zoisite
Shale	Tourmaline	
Volcanic		
Zircon		

† After Tickell, F. G., Examination of fragmental rocks, p. 82, Stanford University Press, 1931.
* Abundant.
** Very abundant.

on the other hand, is a measure of the tension between two liquids in contact or between a liquid and a solid. Interfacial tension may be defined as the contractile force in dynes per centimeter operating at the plane of the interface between the two liquids or the liquid and the solid and at right angles to it.[18]

To understand the interplay of these forces, consider any solid surface. The molecules within the mass of the solid exert attraction toward one another, these forces being in a condition of resultant equilibrium. The molecules on the surface of the solid, however, have forces exerted on them only by the molecules below them, and the system is in a state of unbalance. Free surface energy tends toward a minimum by attracting molecules of other substances onto the surface. If there is more than one substance in contact with the solid surface (for example, two different liquids) the solid surface will attach to itself the substance which will reduce the free surface energy by the greatest amount. Thus pure water will displace most hydrocarbons from a silica surface because water has a greater adhesive tension and will reduce the system to a lower level of energy than will oil.

The classical example of adhesion tension relationships has been presented by Benner, Riches, and Bartell.[19] In figure 1, S_{so}, S_{sw} and S_{ow} represent respectively the interfacial tensions at the solid-oil, solid-water and oil-water interfaces.

If S_{so} is greater than S_{ow} plus S_{sw}, the water will spread over the surface of the solid, completely displacing the oil. However, if S_{so} is less than S_{ow} plus S_{sw}, the system will come to equilibrium at some definite

---

[18] Getman, F. H., and Daniels, F., op. cit.
[19] Op. cit.

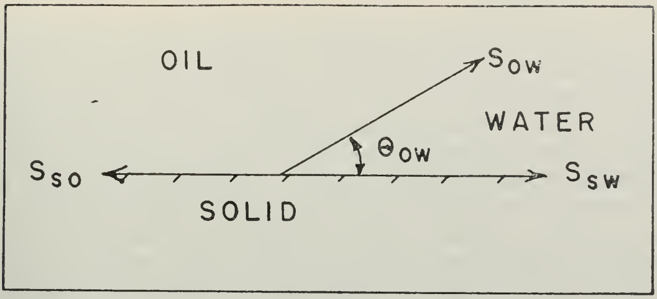


FIGURE 1.

contact angle θ_{ow}, as measured through the water phase. Therefore, at equilibrium,

$$S_{so} = S_{sw} + S_{ow} \cos\theta_{ow}$$
$$\text{or } S_{so} - S_{sw} = S_{ow} \cos\theta_{ow}$$
$$\text{and } S_{so} - S_{sw} = A_{sw} - A_{so} = S_{ow} \cos\theta_{ow}$$

where A is the corresponding adhesion tension.

The magnitude of A_{sw} and A_{so}, the adhesion tensions of water and oil respectively against a solid, determine whether the solid will be preferentially wet by water or by oil. If A_{sw} is greater than A_{so}, which is generally the case, the solid will be preferentially wet by water. Although it is not possible to measure interfacial tensions between liquids and solids directly, it can be seen from the above relations that the difference between the two tensions may be calculated if the values of S_{ow} and θ_{ow} are known. Benner and Bartell have shown θ_{ow} to be about 30° for water and pure hydrocarbons on both silica and calcite. These two minerals, as well as most others, are hydrophilic in nature, and, as is to be expected the contact angle would be less than 90° and the grains preferentially wet by water. There is a complication in the above reasoning for Benner and Bartell [20] have found that some crude oils may deposit polar impurities on the mineral grain surface and as a result the mineral becomes hydrophobic, that is, the contact angle is increased to greater than 90°.

Unfortunately, there are few data available as to the relative degree of wettability of the various mineral components of a reservoir sand. The information available has been summarized in a very general way by Garrison.[21] His information indicates that alumina, fluorite, and barite do not differ appreciably from silica in their affinity for oil and that materials such as clay, aluminosilicates of the metals, and hydrated silicic acid, which form a part of the cementing material of resevoir sands, will be found to have even greater affinity for water and less for oil than purified silica.

Although the foregoing demonstrates the importance of surface forces in petroleum reservoirs, the variation of these forces with mineral content appears to be of negligible significance unless consideration is given to the characteristics of the displacing fluids. This matter will be discussed in some detail in a later section.

---

[20] Benner, F. C., and Bartell, F. E., The effect of polar impurities upon capillary and surface phenomena in petroleum production: Am. Petroleum Inst. Drilling and Production Practice, pp. 341-348, 1941.

[21] Garrison, A. D., Selective wetting of reservoir rock and its relation to oil production: Am. Petroleum Inst. Drilling and Production Practice, p. 130, 1935.

Clays in Reservoir Sands

Clays are nearly always present to some extent in sedimentary formations. Although the clay content of oil-producing sandstones generally ranges from small to minute, the importance of its influence on the overall problem of flow through porous medium and the displacement of oil by water has been seriously neglected. Clay may occur in a sandstone as individual particles widely dispersed throughout the sand grains; it may occur at and around the points of contact between sand grains; or it may occur as a coating on the sand-grain surfaces, thus lining each pore space with a coating of clay. The total clay content of a sandstone may be exceedingly small by weight or by volume, yet, because of its extremely fine particle size, this small amount of clay is capable of covering a large surface area.

Before proceeding further, it may be well to investigate the several types of clay and the properties of these clays which may be of importance in water-flooding. Clays in general consist of a group of complex hydrous aluminosilicates commonly referred to as the ''clay minerals.'' Clays[22] are generally micaceous in habit and because of their resultant lattice structure, they are referred to as ''platy.'' The individual clay particles have appreciable breadth and width but are of extremely small dimension in the third direction. As a result of this minute third dimension, clays exhibit colloidal properties, so that such factors as degree of hydration of each particle, adsorption of ions, and particle charge are important.

Clays have long been considered as the end products of weathering and in general are thought to be quite stable. Grim[23] points out that this statement is not necessarily true for great changes in structure, composition, and properties of a clay may take place upon changes in its environment. Thus it would appear that more than one type of clay mineral could be formed from the same source material if environmental conditions such as alkalinity of the water, character of the dissolved salts, temperatures, rates of accumulation, etc., were different. Grim indicates the possibility of deducing the depositional environment from the properties of the clay mineral.

A tentative classification of clay minerals is presented in table 4.[24, 25].

Table 4. Tentative classification of clay minerals.

1. Montmorillonite group	
a. Montmorillonite	$(OH)_4$ $(Al_4\ Mg_4\ Mg_6\ Fe_4)$ Si_8O_{20} nH_2O
(1) Nontronite	$(OH)_4$ Fe_4 Si_8O_{20} nH_2O
(2) Saponite	$(OH)_4$ Mg_6 Si_8 O_{20} nH_2O
b. Beidellite	$(OH)_4$ $(Al_4\ Mg_6\ Fe_4)$ $(Si_{6-y}Al_y)$ O_{20} nH_2O
2. Kaolinite group	
a. Kaolinite	$(OH)_8$ $Al_4Si_4O_{10}$
b. Dickite	$(OH)_8$ $Al_4Si_4O_{10}$
c. Nacrite	$(OH)_8$ $Al_4Si_4O_{10}$
d. Anauxite	$(OH)_8$ $Al_4Si_4O_{10}$ $nSiO_2$
e. Halloysite	$(OH)_8$ $Al_4Si_4O_{10}$ nH_2O
3. Illite group	
a. Illite	$(OH)_4$ K_y $(Al_4\ Fe_4\ Mg_4\ Mg_6)$ $(Si_{6-y}Al_y)$ O_{20}

---

[22] The term "clay" as used in this report refers to "clay minerals" alone although the term is commonly used to denote any mineral grains below a certain size.

[23] Grim, R. E., Relation of clay mineralogy to origin and recovery of petroleum: Am. Assoc. Petroleum Geologists Bull., vol. 31, pp. 1491-1499, 1947.

[24] Grim, R. E., op. cit.

[25] Miller, L. E., Fundamental chemistry of the effects of hydrogen ions on water-intake rates of oil sands: Prod. Monthly, vol. 11, no. 1, pp. 35-38, November, 1946.

Montmorillonite, the predominant mineral of bentonite, is derived from latitic and rhyolitic rocks normally of volcanic origin and low in Fe_2O_3.[26] It is micaceous in habit, consisting of platy crystals having appreciable size in two dimensions and colloidal size in the third. Because of this platy texture, it is possible for water to penetrate between the plates and cause pronounced swelling, separation of the plates, and eventually complete dispersion. It has been stated that a cube of montmorillonite can absorb 13.8 times its volume in water without losing its shape, and also that it may require 1000 percent or more, by weight, of added water to cause complete dispersion of the clay particles.[27] The lattice structure of montmorillonite is very complex; it probably owes its lack of stability to the proximity of $O^=$ atoms to successive units which build up the crystal with a resulting repelling effect.[28] In montmorillonite, ions of lower valence display a tendency to replace both the aluminum and silicon, leaving unbalanced charges which are neutralized by such bases as sodium, calcium, and magnesium. Such replacement gives rise to the high base-exchange capacity so common to montmorillonite.

Clays of the kaolinite group, although also displaying a platy, lattice structure, are much more stable than montmorillonite because H^+ and OH^- groups occur side by side in the successive units building up the crystal structure. Thus the repelling forces within the lattice are minimized in the case of kaolinites. As the valency requirements within the structure are balanced, there is little tendency for the aluminum to be replaced by iron, magnesium, etc., and the base-exchange capacity of kaolinites is very low. Kaolin-type clays are capable of absorbing only relatively small amounts of water (from 50 to 100 percent by weight of the dry clay) and their swelling capacity is correspondingly reduced.[29]

Comparatively little is known about illite, the third type of clay mineral, but it is thought to be one of the major clay constituents of many oil-bearing strata.[30] Ross and Hendricks [31] state that illite is not strictly one of the clay minerals but is related to the micas and may be included in the group of "hydrous micas". However, as far as its colloidal behavior is concerned, illite appears to be closely related to the montmorillonite group but somewhat intermediate between it and the kaolinites. Griffiths [32] points out that illite differs from montmorillonite in that some of the repelling charges of the oxygen in the lattice structure are neutralized by a base, generally potassium. This gives rise to the concept that illite is in reality an isomorphous series dependent upon the amount of potassium present, which explains the highly variable base-exchange capacity of the illites. Some illites are almost as stable as the kaolinites; others approach the montmorillonites in lack of stability.

---

[26] Miller, L. E., op. cit.

[27] Griffiths, J. C., Clay research and oil development problems: Inst. Petroleum Jour., vol. 32, no. 265, pp. 18-31, 1946.

[28] Miller, L. E., op. cit.

[29] Griffiths, J. C., op. cit.

[30] Bates, T. F., Gruver, R. M., and Yuster, S. T., Influence of clay content on water conductivity of oil sands: Oil Weekly, vol. 123, no. 8, p. 48, 1946.

[31] Ross, C. S., and Hendricks, S. B., Minerals of the montmorillonite group: U. S. Geol. Survey Prof. Paper 205B, pp. 23-79, 1945.

[32] Op. cit.

The swelling of clays when in contact with water is of obvious importance in water-flooding. It is generally considered that in most petroleum reservoirs a certain amount of water is present and that any clay present therein would occur in a swollen condition. It is probable that the addition of more water would lead to even greater swelling and splitting of the clay particles into thinner and thinner laminae. Both of these reactions would lead to plugging of the minute interstices between sand grains and would greatly impair the movement of fluids through the reservoir. However, probably much more important than this *additional* swelling of the clays is the matter of base-exchange. Base-exchange properties are more pronounced in montmorillonite than in other clay minerals. The following discussion is confined to montmorillonite, though it also applies in a lesser degree to the other clay groups.

There is a general tendency for ions of lower valency (iron, magnesium) to replace both aluminum and silicon in the montmorillonite structure. This leaves the structure with unbalanced charges which are neutralized by cations such as sodium, calcium, and hydrogen. It is further possible for these cations to replace each other, still without destroying the original crystal structure of the clay particle. There is a certain order in which base replacement should occur at equivalent concentrations. For example, calcium will tend to replace sodium. However, Griffiths[33] points out that this property is dependent on many other factors such as the nature of the original exchange, size of the cavity within the lattice through which the ion must pass, size of the ion, and size of the clay particle.

Clays may be divided into three general classes according to their base type. Hydrogen-base clays have the greatest water absorption ability; however, they are not thought to be present in petroleum reservoirs. The second type, calcium-base clays, occur in a flocculated condition and are the most permeable of all clays. Calcium-base clays are very common, probably because of the high replacement ability of the calcium ion. Sodium-base clays, the third type, have a much higher water absorption capacity than calcium clays, exist in a deflocculated condition, and are relatively impermeable. Although sodium-base clays are permeable to sodium chloride solutions, they are practically impermeable to fresh water.

Grim[34] gives an excellent discussion of what probably occurs in a petroleum reservoir in which a small amount of montmorillonite is present. He points out that where the clay is in an air-dried state, a layer of water a single molecule thick will be present between the lattices of the clay crystal if the cation is sodium, whereas the layer of water will be two molecules thick if calcium is the cation. This follows from the difference in valence of the two cations. In the presence of large amounts of water, the water layers for the sodium-base clay become infinitely thick, limited only by the amount of water present. However, in the case of calcium-base clays, the water layer is but a few molecules thick regardless of the amount of water present. This can be observed in the deflocculated and flocculated conditions, respectively, of the above clays. If water moving through the calcium-base clay had a certain sodium ion concentration, base-exchange would occur, disrupting the water absorption equilibrium of the clay. Thus as sodium cations replaced the calcium cations, more and more water would be absorbed, separation of the individual laminae from the clay particles would occur, and, as a result, the sand would become seriously plugged. If the water contained calcium rather than sodium, no net reaction would occur, except for the completion of the water saturation if the calcium-base clay were not in a condition of equilibrium. In the case of sodium montmorillonite, sodium-bearing water passing through the sand would cause no base exchange, and, the only reaction would be to complete the water saturation of the clay. It would probably be difficult to promote the passage of water containing calcium through a sand containing appreciable amounts of sodium-base montmorillonite because of the deflocculated condition of the clay and its impermeability to any but sodium water. If the sand contained a small amount of clay, base-exchange would probably occur, with a resultant shrinking of the clay particles and improvement of the water conductivity of the sand.

---

[33] Op. cit.
[34] Op. cit.

The above reactions would be far less pronounced if some clay mineral other than montmorillonite were present in the sand. Kaolinite is much more stable, having much more tendency to break up into individual laminae, and having a low base-exchange capacity. Illite is intermediate in these respects and its degree of reaction would probably depend upon its potassium content.

In nature, it is common to find intimate clay mixtures. For example, it is believed that montmorillonite may occur in the form of unit laminae interbedded between layers of illite.[35] This results in planes of weakness within the illite structure which may cause a net reaction nearly as acute as in the case of pure montmorillonite. Thus, the presence of montmorillonite in a sand, even in minute quantities, may have a pronounced influence on its fluid conductivity.

To date, little is known of the surface effects of clay minerals; yet, because of the tremendous surface area exposed by clays, this matter should be of some importance. As far as can be determined from the literature on the subject, the wettability characteristics of clays have not been investigated. Nevertheless, it is a well-known fact that clays in general are hydrophilic in nature. There is an important aspect of forces active on the surface of clay minerals which should be mentioned. Montmorillonite is valuable in certain refinery processes because of its ability to adsorb hydrocarbons on its abundant surfaces. Grim[36] believes that some hydrocarbons are probably adsorbed on the clay surfaces within the oil sand but that an attempt to displace the hydrocarbons with injection water would probably result in a separation of the clay laminae and a plugging of the pores.

Another aspect of this problem is of considerable significance in water-flooding. The hydrogen ion concentration of the water in contact with a clay has a pronounced influence on the swelling capacity. Miller[37] has analyzed the work of Mattson on this subject and related the findings to water-flooding. The alumino-silicate complexes of which bentonite is made up, absorb or combine with anions in an environment in which the pH value is below the iso-electric point of the complex. Likewise, cations are absorbed at pH values above the iso-electric point. It has also been noted that the farther the system is removed from the iso-electric point of the clay, the greater is the swelling capacity of the clay. Clays common to oil-bearing reservoir sands have an iso-electric point well on the acid side of neutrality. To maintain clay swelling at a minimum, the injection water should likewise be acidic and as close as possible to the iso-electric point of the clay. It is hardly possible that flood waters having a pH value sufficiently below the iso-electric point to increase swelling on the acidic side would be employed, for corrosion problems would then become paramount.

---

[35] Grim, R. E., op. cit.

[36] Op. cit.

[37] Op. cit.

It would be well at this time to summarize the above information and relate it to the present problems of water-flooding. In general, it can be stated that the presence of clay even in minute quantities in a sand being considered for water-flooding, may be highly detrimental. The degree of influence of the clay content will be dependent on three factors, namely: (1) type of clay, whether it be montmorillonite, kaolinite, illite, or some other; (2) base of the clay (sodium, calcium, etc.); and (3) chemical nature of the flood water. It is very important that the first two factors be carefully determined, bearing in mind the importance of even minute quantities of montmorillonite and certain forms of illite. The third factor, that of the chemical nature of the flood water, is also critical, and is to be conditioned by the first two factors.

Cementing Materials

The third and final constituent of the porous medium to be considered is the cementing material which binds the individual grains together to form a coherent mass. This cementing material is probably of much greater importance than has been recognized previously. Its importance in determining such physical properties of the medium as porosity and permeability is more or less obvious, but the fact that cementing material may be present in such quantities as to coat most of the grain surfaces, thus masking their true surface effect, has been somewhat neglected.

The common types of cements may be classified into three groups: the soluble salts such as anhydrite gypsum, calcite, dolomite, and limonite;[38] the clay minerals; and the relatively insoluble siliceous materials. Percolating ground water rich in dissolved minerals may precipitate or redeposit part of its mineral content within the pore spaces of the sand. This deposition may occur as crystals within the pore, at the points of contact between the sand grains, as renewed crystal growth, or as a coating on the original grain surfaces.

Waldschmidt [39] states that the secondary deposition of calcite and dolomite is extremely variable in amount and distribution. Secondary carbonates may occur as small isolated crystals widely dispersed throughout the sand body; as segregated masses or clusters of crystals; or as the groundmass in which sand grains are imbedded. Gilbert [40] has observed in studying California sandstones that secondary calcite crystals commonly begin their growth within one pore, completely filling the pore and expanding into adjacent pores as one continuous crystal.

Clay minerals may be considered as cementing materials only in the sense that they aid the compaction of the sand by partially filling the pore spaces. In this respect, clay is important in its occurrence at and around the contact points of the grains themselves. Clay and other extremely fine-grained material such as biotite, sericite, and chlorite commonly occur as coatings on the sand-grain surfaces. In his analysis of the Third Bradford sand, Krynine [41] has found that although the clay content of this sand does not exceed 15 percent and is usually between 3 and 10 percent, the pore walls may be lined with clay in amounts of 20 to 30 percent of the wall area. He found further that the larger pores may be lined with clay to the extent of 20 to 45 percent, intermediate pores from 40 to 60 percent, and the finest pores from 60 to 80 percent.

---

[38] Occurring as colloidal suspension.

[39] Waldschmidt, W. A., Cementing materials in sandstones and their probable influence on migration and accumulation of oil and gas: Am. Assoc. Petroleum Geologists Bull., vol. 25, p. 1839, 1941.

[40] Gilbert, C. M., Cementation of some California Tertiary reservoir sands: Jour. Geology (in press).

Comparatively small amounts of siliceous materials are carried in a dissolved state in percolating ground water. Silica cementation is thought to be largely a result of the welding together of grains of a similar composition by the process of solid solution under extreme pressures.[42] Silica dissolved at intergrain contacts is redeposited as renewed crystal growth on detrital grains. This is apparently true in the case of both quartz and feldspar and possibly even with other siliceous minerals. The net effect of this reaction is to form an interlocking grain pattern with reduction in porosity of the sandstone.

As far as surface forces are concerned, cementation by silica or carbonates has little effect. The only effect might be that new and clean crystal faces are presented on which surface reactions may be somewhat different than on the original eroded surfaces.

Summary and Correlation to California Conditions

In summarizing the influence which the mineral content of reservoir sands may have on water-flooding, it appears that the clay content is of the greatest significance. Clay, even in small quantities, may coat a large part of the pore surface because of its extremely fine particle size. This will influence both the action of the surface forces and the physical properties of the sand. The reactive capacity of a clay depends both on its type and its base. Sodium montmorillonite has the greatest swelling capacity of all the clays and its presence even in small quantities can effectively block the sand to the flow of fluids. Illite and kaolinite are less reactive in this respect.

The variation of adhesive and displacement forces with mineral type alone is probably not of appreciable importance. Consideration must be given to the multi-component system—reservoir water, reservoir oil, and reservoir mineral content— to gauge the magnitude of these forces.

Cements are of importance principally for their effect in masking the surface characteristics of the mineral grains.

California reservoir sands are generally arkosic although the other two types, quartzose and graywacke, are sometimes encountered, depending upon the geologic epoch and the geographic region. They are characterized by poor sorting of mineral assemblages and sand-grain size and frequent interbedding of shales.[43] The quartz to feldspar ratio is widely varient between less than 1:1 and greater than 10:1. Interbedding of limestone is rather rare but the sands are sometimes cemented with carbonates. For the most part, California sands are unconsolidated or semiconsolidated.

---

[41] Krynine, P. D., Petrology and genesis of the Third Bradford sand: Pennsylvania State Bull. 29, 1940.

[42] Waldschmidt, W. A. op. cit., Gilbert, C. M., op. cit.

[43] Reed, R. D., Position of California oil fields as related to geologic structure: California Div. Mines Bull. 118, p. 97, 1943.

The clay content of these sands is probably rather high although there are few analyses available to indicate types and amounts. It is common practice to indicate clay content by terming the sand as ''clean'' or ''dirty''. Thin-section studies have indicated a clay content as high as 15 percent in cores from some California fields. Johnston and Beeson [44] in their work on permeability present some of the best evidence available to indicate the high clay content of many California reservoir sands. Their analysis of about 2000 core samples from various parts of the state showed permeability to air to be many times that to fresh water with permeability to salt water somewhat intermediate between the two. This can only be explained as due to an appreciable content of reactive clay.

Johnston and Beeson have also suggested that the lack of effective water drive in several California fields may be attributed to the high clay content of the reservoir sands. This and other evidence presented seems to indicate that as far as the influence of mineral content is concerned, the most important problem in California, as elsewhere, will be in overcoming the adverse effects of the presence of clay in the sands. No statement can be made regarding the influence of surface forces until the liquid components have been discussed.

Physical Properties of the Porous Medium

The importance of the solid phase of the porous medium in waterflooding has been demonstrated in the preceding section, but probably of equal importance are the properties of the void phase within the medium. It is this portion of the medium which offers a storage space for hydrocarbon fluids and flow channels through which the fluids must pass in reaching the well-bore. These properties, for the most part, are determined by the texture of the sand. Texture denotes the disposition and manner of union of the particles making up the sandstone. The reciprocal of texture, commonly referred to as ''pore pattern,'' [45] is probably of greater importance in this respect. The pore pattern may be considered to be composed of two parts, the larger voids existing between sand grains, and the smaller interstices interconnecting the voids. In general the larger voids furnish the greater part of the storage capacity of the porous medium. The small interstices interconnecting the pores, being capillary in size, exert an important influence on the fluid-conducting ability (or permeability) of the porous medium for it is through these minute openings that the greatest resistance to flow is met.

Texture and Pore Pattern

The texture and pore pattern of a sandstone are conditioned by many factors as are the resultant properties of porosity and permeability. The size and size distribution of the component sand grains determines the size and number of openings between the grains; the larger the grains, the larger are the pores, and the less abundant they are per unit volume of sandstone. The shape, or sphericity, and the ''degree of roundness'' of the component grains are determining factors in the texture or pore pattern. The greatest porosity of a sandstone would be obtained by cubic packing of perfectly spherical grains of uniform size. Certain arrangements of needle-like or platy grains would result in a much greater porosity but grains of such shapes are not common to, or at least not abundant in, sandstone reservoirs. The general statement can be made that the greater the angularity of the grains, the less will be the porosity of the sandstone.

---

[44] Johnston, N., and Beeson, C. M., Water permeability of reservoir sands: Am. Inst. Min. Eng. Trans., vol. 160, pp. 43-55, 1945.

[45] Krynine, P. D., Mineralogy of water flooding: Prod. Monthly, vol. 3, no. 2, p. 10, 1938.

Another important factor influencing the pore pattern is the degree of compaction of the original sediment. Obviously, the greater the pressure applied to an unconsolidated sediment, the greater will be the compaction and the smaller will be the pore spaces. Most reservoir sands are encountered at moderate to great depths, the weight of overlying rock masses tending to reduce the sediment volume to a minimum. Also important in this respect are the forces of diastrophism which may impose much greater pressures on the sedimentary formation than could be attributed to the weight of the overlying rock masses alone. Some authorities [46] state that such pressures may be sufficient to cause the union of grains of like minerals by the process of solid solution. This type of cementation would again reduce the void volume. In the case of sediments in which the grains are firmly cemented in place prior to the application of extreme pressure by overlying rock masses, little compaction will occur and the void volume will remain unaffected. On the other hand, diastrophic forces may tend to fracture and crush cemented sediments, perhaps even increasing the porosity and fluid conductivity.

Cementation plays a very important role in the formation of the pore pattern. Regardless of the type of cementing material involved, this process always decreases the pore volume. The three common types of cementing material mentioned earlier (silica, carbonates, and clay) may, however, be effective in reducing the pore volume in different ways. Krynine [47] has listed the factors effective in the Bradford sand as welding of quartz grains, cementation by carbonates, and adhesion by clay particles. Gilbert,[48] in thin section studies of certain California sandstones, derived a textural classification which, in essence, was based on the above three factors.

To understand the variations found in pore patterns, it is necessary to review the processes of cementation. The interlocking grain pattern often found in quartz sandstones cannot be explained on the basis of sedimentation and compaction alone. The interlocking of grains is so complete as to indicate that welding by differential solution between grains must have occurred. Waldschmidt [49] has explained this process as follows. The extremely minute quantities of dissolved silica in normal ground waters are not sufficient to account for the secondary deposition of quartz commonly found in sandstones of this type. The extreme pressures encountered at the points of contact between grains is probably sufficient to cause the solution of silica into the surrounding water. However, since the hydrostatic pressure within the pore is much less than the pressure at the points of contact, the dissolved silica is immediately redeposited on the boundary of the pore. This action usually results in renewed crystal growth on the sand grain bordering the pore, with the identical crystallographic orientation. In some cases this growth may be independent of the sand grain orientation. This process continues until either the pore is completely filled with recrystallized quartz forming the interlocking pattern noted above, or the contact pressure becomes insufficient to cause further solution. Gilbert[50] has observed that this same pattern may also be found in the case of feldspars and rarer minerals such as zircon and can probably be explained by the same process.

---

[46] Krynine, P. D., Petrology and genesis of the Third Bradford sand; Pennsylvania State Bull. 29, 1940.
Gilbert, C. M., op. cit.
Waldschmidt, W. A., op. cit.

[47] Op. cit. (1940).

[48] Op. cit.

[49] Op. cit.

Waldschmidt states that the precipitation of quartz is uniform throughout a sand body. As a result, the smaller pores in fine-grained sands are more completely filled than pores in coarser sands, in a given period of time. It has also been noted that the presence of clay in the pore spaces limits the amount of differential solution. This may be explained on the basis that the clay absorbs and redistributes the stress due to the weight of overlying rock sufficiently to reduce contact pressure below that necessary for solution.[51]

The nature of secondary carbonate deposition has already been discussed. Carbonates are sufficiently soluble in ground waters to explain the source of the large amount of this type of cementing material found in many sandstones. Contact pressure may, however, increase the amount of carbonate dissolved and recrystallized. The precipitation of carbonates from ground water is attributable to changes in pressure and temperature, a decrease in either or both causing precipitation. Precipitation may also result from chemical reactions occasioned by two ground waters of different types contacting each other.

The effects which carbonates may have on pore pattern apparently depend upon the amount and type of carbonates available for precipitation. Gilbert noted that dolomite generally occurs as small crystals within the open pore spaces or within the clay matrix filling the pore. Occasionally, granular aggregates are formed that completely fill the pore space. Calcite is generally found in granular form filling the pore spaces, or as large crystals enclosing many detrital grains.

Cementation by clay is primarily due to adhesion resulting from the compaction of detrital clay within the pores. Recrystallization of detrital clay is common, making it a more effective binding agent.[52]

Since the recrystallization of silica apparently proceeds at about a uniform rate in all pores, the effect is to decrease pore size constantly until the pore is completely filled, the smaller pores filling first. Since ultimate pore size and size distribution are directly related to the amount of cementation, porosity and permeability decrease directly with increase in cementation. Carbonate cementation results in a somewhat different pore pattern. As some pores are being completely filled with carbonates, others show no appreciable change. Therefore, instead of a uniform decrease in pore size, decrease is mainly in the total number of pores. Although porosity will decrease in proportion to the amount of cementation, this will not necessarily be the case with permeability. Permeability would probably decrease at a lesser rate because full-sized pores would still be available to flow. The effect of clay on pore pattern is obvious. As compaction proceeds, the pore volume becomes smaller and the percentage of the volume occupied by clay becomes greater.

---

[50] Op. cit.
[51] Gilbert, C. M., op. cit.
[52] Gilbert, C. M., op. cit.
Waldschmidt, W. A., op. cit.

The above information on pore pattern was deduced mostly from thin-section analysis. With this type of analysis, it is difficult to visualize the third dimension of the pore network. The use of wax casts is very helpful in obtaining the true three-dimensional pattern. Ryder,[53] in examining wax casts of the pores of Bradford sand, found the pores to be very thin, relatively very wide, and essentially flat. Most of the pores were approximately 1 micron in thickness and from 50 to 100 times as wide. It can be seen, in this case, how important surface and capillary forces become. Similar molds of sandstones from many other locales would be necessary to determine whether these characteristics are predominant.

Porosity

The porosity of a porous medium is defined as the fraction or percentage of void volume per unit volume of the medium. A distinction must be made between ''total'' and ''effective'' porosity—the former including all of the pore space within the medium, the latter referring only to those pores which are interconnected. A certain proportion of the pore spaces in most sandstones is isolated, having no inlet or outlet to other pores, and does not add to the storage capacity of the rock.

Porosity is, of course, important in water-flooding in that it indicates the amount of fluid that may be stored per unit volume of reservoir sand. Van Wingen [54] has more or less arbitrarily stated that porosity should be 25 percent or more for successful water-flooding. This, however, need not be interpreted strictly as a minimum value, for other variables may be sufficiently favorable to justify water-flooding at a considerably lower porosity.

Little further need be said in regard to porosity except to make one precautionary note. Most porosity determinations are made with thoroughly cleaned and dried core specimens. In the case of sandstones with an appreciable clay content, drying of the specimen removes absorbed water from the clay leaving it in the smallest possible volume. As a result, porosity as determined on a dried core specimen is not indicative of the porosity of the same specimen as it would exist in the reservoir. On the other hand, if the original water saturation of the core be known accurately, this need not be a matter of concern.

Permeability

The permeability of an oil reservoir is very important in water-flooding for it determines the ability with which fluids flow through the reservoir rock. High permeability is normally desirable in a petroleum reservoir because less energy is required to cause movement of fluids through the sands. In the case of water-flooding, this is true only to the extent that there is some minimum value, perhaps 50 millidarcys, below which it would not prove economical to water-flood. From this standpoint, it is strictly a problem of economics, for the producer must be able to recover oil at a certain rate, the rate being determined by the permeability, in order to realize a profit from the undertaking. However, from the standpoint of ultimate recovery, it is believed that, within limits, lower permeability may lead to increased recovery. This is an attribute of the greater efficiency of oil displacement at lower rates of water advance, as would occur in low permeability sands. The displacement of oil by water from the sand-grain surfaces is a slow process and the higher rate of flow in sand of high permeability does not permit the establishment of equilibrium. There are numerous other factors of equal importance which will be discussed at some length in the following paragraphs. Those having the most pronounced influence are permeability variations within the reservoir, and relative permeability.

---

[53] Ryder, H. M., Character of pores in oil sand: World Oil, April 1948, pp. 129-134.
[54] Van Wingen and Johnston, op. cit.

The permeability of a porous medium is determined, in general, by the texture or pore pattern of the medium and, in particular, by the size and abundance of the small channels interconnecting the larger pores. That the size of the flow channels is important is obvious from the fact that smaller channels restrict flow because of greater frictional loss and greater capillary drag. Likewise, the fewer the flow channels, the less will be the fluid conductivity of the medium.

All of the many factors which influence pore pattern also have a strong bearing on the permeability. Although there is not necessarily any relation between permeability and porosity, approximate relations may be derived considering both porosity and pore pattern. Cementation influences permeability in that the presence of the cementing material reduces the net flow area. However, it should be borne in mind that in the case of unconsolidated or loosely consolidated sands, the finest material may have mobility, that is, the flow of fluid through the sand may dislodge the fine grains, transport them through the pore spaces, and redeposit them in the finer restrictions, with a resultant reduction in the permeability of the sand. The same action may occur in well-consolidated sands, although to a lesser degree for, even though the principal grains are retained in a permanent position, the grain surfaces are commonly coated with clay and other exceedingly fine-grained minerals which may have some degree of mobility.

The orientation of mineral grains within the medium is important in that it determines the shape and orientation of the pore spaces. Ordinarily, the deposition of mineral grains is such as to orient the grains to the position of greatest stability. Thus platy and needle-like grains are oriented parallel to the planes of deposition. As a result, permeability is generally found to be greater and more uniform laterally than vertically. Only in the case where deposition is extremely rapid or where sand grains are well rounded and no platy minerals are present would uniform permeability in all directions be expected.

Permeability not only varies in different directions, but also varies pronouncedly in any one direction. It is common to find widely varying permeabilities in the same direction in adjacent core samples. Thus, in calculations involving permeability, great caution must be exercised in selecting a value truly representative of the formation considered. This problem is not, however, as acute as it may appear, for it has been found that for comparatively uniform formations, an average or mean of several permeability values will yield a resulting value which may be used with considerable confidence. In relation to the method of deriving such a value, Cardwell and Parsons[55] have shown that the effective permeability of a formation lies between the harmonic and arithmetic means of the individual permeability values but that, in most cases, an arithmetic average is satisfactory.

---

[55] Cardwell, W. T., and Parsons, R. L., Average permeabilities of heterogeneous oil sands: Am. Inst. Min. Eng. Trans., vol. 160, pp. 34-42, 1945.

Of greater importance than this microscopic variation in permeability is the regional change found in lenticular and stratified deposits. Highly erratic processes of deposition generally result in the presence of localized lenses of so-called ''loose'' or ''tight'' sands within the formation, which may display otherwise fairly uniform permeability. This condition is probably more common in California oil fields than in those of any other locale and is a matter of concern not only in secondary recovery but in primary recovery as well. Where localized areas of low permeability occur, natural and artificial expulsive forces tend to bypass and leave unrecovered the oil within these areas. Likewise, loose streaks or lenses within the formation provide escape channels for the fluid, and as a result a portion of the oil in the main sand body is bypassed. Permeability may also vary more or less uniformly laterally within a field, very permeable sands in one portion of the field grading into tight sands in another portion. This is a problem of considerable concern to all oil producers. On the other hand, the existing permeability irregularities in older fields have caused the bypassing of considerable oil, unrecoverable by normal recovery methods which may, however, be available for secondary recovery. However, the difficulties of secondary recovery are increased, for satisfactory methods of selective plugging of loose sands and selective shooting of tight sands must be developed and employed. Considerable knowledge of the permeability variation within the reservoir must be at hand to deal effectively with this problem. Such information is generally not available in the case of the older fields and new wells may have to be drilled to obtain this information.

Permeability is usually determined by passing dry air through cleaned and dried core specimens. Darcy's law postulates permeability to be dependent only on the characteristics of the porous medium itself and to be independent of the nature of the fluid flowing through it. That this is not strictly the case has been shown by several investigators.[56] Klinkenberg [57] has shown permeability to gas to be dependent upon the nature of the gas. Darcy's law assumes (or it is valid only for) viscous, laminar flow with a normal velocity distribution of zero at the walls of the flow channel and a maximum at the center of the channel. Gases flowing at low pressures through channels of capillary size display the property known as ''slip,'' that is, the gas particles along the walls of the channel have a velocity different from zero. The amount of slip is proportional to the mean free path of the gas molecules which in turn is inversely proportional to the pressure. On the basis of the Maxwell distribution law, Klinkenberg has developed a relation between the apparent and true permeability of an idealized porous medium as follows:

$$K_a = K\left(1 + \frac{b}{\bar{p}}\right)$$

where ''$\bar{p}$'' is the mean pressure and ''b'' is a constant which is inversely proportional to the radius of the capillaries of the idealized porous medium. As would be expected from this relation, and as verified by experiments, the deviation from Darcy's law would be greater at low pressures and in finer sands. Klinkenberg concludes that gas permeability is a linear function of the reciprocal mean pressure and that the apparent permeability extrapolated to infinite mean pressure should give the true permeability.

---

[56] Johnston, N., and Beeson, C. M., op. cit.
Klinkenberg, L. J., The permeability of porous media to liquids and gas: Am. Petroleum Inst. Drilling and Production Practice, pp. 203-213, 1941.

[57] Klinkenberg, L. J., op .cit.

In the case of liquid permeability, it has been found that if no changes in the internal structure of the medium occur, permeability is independent of the nature of the liquid and is comparable with "true" gas permeability. A few liquids do, however, promote an electro-kinetic effect which results in a small deviation. The characteristics of these liquids (that is, the value of zeta potential, dielectric constant, and specific conductivity) are such as to cause an electro-endosmotic flow, when the liquid flows through a porous medium, which is opposite in direction to the hydrodynamic flow.[58]

Although the above cited examples of deviation from Darcy's law are important, probably of even greater importance are the changes which may occur in the porous medium itself as a result of the reaction of liquids upon the constituents of the medium. Permeability as determined in the laboratory using dry air may bear no relation to the permeability of the same specimen as it existed in the reservoir. The importance to permeability of the effect of the swelling of clays in contact with reservoir or injection water has been discussed at length in an earlier section. The work of Johnston and Beeson [59] has aptly demonstrated the tremendous differences which may be found in the permeability of the same specimen to air, fresh water, and salt water. In all cases, the permeability to fresh water was found to be considerably less than salt-water or air permeability. The authors state that probably the salt water permeability values are more representative of reservoir permeability than either those of air or fresh water. In this connection, the most reliable permeability value could probably be obtained by using the same fluid that exists in the reservoir as the flow liquid.

In actual petroleum reservoirs, permeability relations are complicated by the fact that not one but three fluids (gas, oil, and water) are present and flow in mutual contact with one another when a pressure gradient exists. Because of the marked difference in viscosity of these three fluids, each is capable of flowing through a reservoir sand of a given permeability with a different degree of ease, inversely proportional to the viscosity of the fluid. Wyckoff and Botset [60] and others [61] have shown that in multi-phase flow through porous media, the relative amounts of each fluid flowing depend not only on the viscosity of the fluid but also upon the relative saturation of the fluid at any particular point within the medium. Relative permeability, which is the ratio of the effective permeability of the particular component to the total or absolute permeability of the medium, is plotted on curves as a function of relative saturation. The ratio of relative permeability to viscosity of the fluid, sometimes referred to as the mobility ratio, is thus a true index of the ability of a fluid to flow.

---

[58] Klinkenberg, L. J., op. cit.

[59] Op. cit.

[60] Wyckoff, R. D., and Botset, H. G., Flow of gas-liquid mixtures through unconsolidated sands: Physics, vol. 7, pp. 325-345, 1936.

[61] Leverett, M. C., Flow of oil-water mixtures through unconsolidated sands: Am. Inst. Min. Eng. Trans., vol. 132, pp. 149-169, 1939.

Leverett, M. C., and Lewis, W. B., Steady flow of gas-oil-water mixtures through unconsolidated sands: Am. Inst. Min. Eng. Trans., vol. 142, pp. 107-116, 1941.

Dickey and Bossler [62] show that in the case of a particular water-oil system, the water-oil production ratio is 1 for an oil saturation of 45 percent and a water saturation of 55 percent, and further, that no oil flowed when the oil saturation was below 15 percent. In another case, a sand having a gas saturation of 70 percent and an oil saturation of 30 percent, the gas-oil ratio was about 10,000 while with the same oil saturation but with 50 percent water and 20 percent gas, the gas-oil ratio was about 5 and the water-oil ratio about 3.

Summary and Relation to California Conditions

The texture and pore pattern of a sandstone are important in that they determine porosity and permeability. The size and shape of the pores are of additional importance in displacement and capillary phenomena. Although porosity is of less importance than permeability, it does indicate the volume available for the storage of fluids.

Permeability and its variations are undoubtedly the most important physical characteristics of the reservoir as far as both primary and secondary recovery are concerned. That permeability is conditioned by such factors as slip and clay content, must be recognized. Both vertical and lateral variations in permeability are common and must be dealt with in developing a water-flooding program.

The relative amounts of fluids flowing through a porous medium are controlled by the viscosity, saturation, and relative permeability of each component. These factors must be known before it is possible to predict the success of water-flooding. That the success of such a project is very dependent upon these factors becomes more apparent in considering the economics involved. Obviously, the permeability must be such as to permit the recovery of oil at a rate sufficient to offset operating expenses.

California reservoir sands are generally poorly sorted as to size. The angularity of sand grains and usual lack of appreciable amounts of cementing material other than clay, result in a medium to high porosity. Permeability is low to medium,[63] as compared with that found in other oil-producing regions. Whether this is an attribute of the high clay content or of the finer grain size of the sand, it is difficult to say. There is no mention in the literature of any investigations of pore size and shape and pore-size distribution having been made on California sands.

Of greater importance than the above factors is the lack of permeability uniformity in California reservoir sands, and this may be the important limiting condition to water-flooding. If these variations are thoroughly understood, it is possible to account for them in the development and completion program. For most of the older fields, however, these data are not available and the cost of obtaining them may be prohibitively high.

Distribution and Nature of Fluids

Modes of Occurrence

An idealized petroleum reservoir is one in which the fluids are distributed by gravity segregation; that is, water occurs in the lower portion of the structure, gas in the top, and oil intermediate between the two.

---

[62] Dickey, P. A., and Bossler, R. B., Role of connate water in secondary recovery of oil: Am. Inst. Min. Eng. Trans., vol. 155, pp. 175-183, 1944.

[63] Van Wingen and Johnston, op. cit.

Although gravity undoubtedly plays an important role in determining the distribution of fluids, other factors have an appreciable influence, especially in the distribution of the liquid phases. In actual reservoirs, water is nearly always present within the oil zone, probably as thin films on the sand grain surfaces and occupying the finer capillary pores. This water is known as connate water, water originally present in the reservoir before the migration and accumulation of oil. In amount it may vary from a small percentage in some reservoirs to well over 50 percent in others. If consideration is given to the interfacial and displacement forces active at the time the oil first migrated into the reservoir displacing water therefrom, it would be expected that the oil would displace only that water present in the larger pore spaces. The greater adhesion tension of the water should prevent oil from displacing the surface film of water on the grain surfaces and the water present in the capillary-size pores. This concept postulates the reservoir to have been originally saturated with water and the mineral grain surfaces ''water-wet.'' Even though this concept may not be exactly correct, the fact remains that water is commonly encountered within the oil zone and to fulfill conditions of equilibrium, its distribution should be as noted above. In the case of reservoir sand containing appreciable amounts of clay and relatively small amounts of water, it is conceivable that all the water may be in combination with the clay and, in effect, removed from the actual fluid part of the system.[64]

Oil Phase

The primary consideration in any water-flooding project is the presence of oil in sufficient quantities to make recovery economically feasible. Oil must be present not only in large quantities, but it must also be present in the reservoir sands in sufficiently high percentage saturation to permit its recovery. The influence of saturation on relative permeability has already been discussed and will be dealt with at greater length in the following section. The importance of the total amount of recoverable oil is obvious for the operator must be assured of an adequate supply of oil, the value of which must more than offset the expense of the project.

The physical and chemical properties of the oil are important in water-flooding. The gravity of the oil is an index of the value of the oil and Van Wingen and Johnston [65] state that gravity should be between 35° and 45° A.P.I. to make the oil of sufficient value to offset the expense of water-flooding. Recent advances in crude oil prices have undoubtedly lowered this minimum figure by perhaps 10° A.P.I. if value alone is considered. Although gravity is generally the principal basis of crude oil valuation, there are other contributing factors. Prices may vary from one field to another because of the difference in transportation costs, demand, and other economic factors. Prices also vary from field to field and even from one zone to another within a field because of differences in chemical makeup of the oil.

Gravity of a crude oil is also an index of its other physical properties, notably viscosity. Almost invariably, the lower the gravity, the higher is the viscosity of the crude. Viscosity is a very important consideration in water-flooding. Regarding it, Van Wingen[66] makes the following pertinent statement:

---

[64] Dickey, P. A., Influence of fluid saturation on secondary recovery of oil: Am. Petroleum Inst. Prod. Bull. 230, pp. 158-164, 1943.

[65] Op. cit.

> "For a displacement mechanism in which a viscous fluid (oil) is driven by means of a fluid of relatively low viscosity (water), an unstable boundary condition will prevail at the fluid interface. This state of instability increases as the relative viscosity difference across the boundary increases. As extensive bypassing results from any disturbance of the boundary equilibrium, it is obvious that a lesser secondary recovery efficiency is to be expected for pools containing high viscosity oil. On the basis of actual field tests, it was indicated that 500 c.p. probably represents the upper limit of permissible reservoir oil viscosity for water flood."

A comprehensive survey of the influence of oil viscosity on secondary recovery has been made by Heath.[67] In summarizing the available information, Heath states that when a field is flooded to its economic water-oil ratio, fields with oil of higher viscosity will yield less oil than those with lower viscosity oil, other conditions being equal. He states further, however, that other factors such as geological and sedimentary characteristics and water and oil saturations of the reservoir probably have a greater influence on the amount of recoverable oil than does viscosity alone, although the effect of this latter factor has not been evaluated by field experiences. Heath concludes that in the case of shallow, less permeable reservoirs, viscosity has a much greater influence on the rate of fluid travel than it has on the residual saturation, from the standpoint of the economics of water-flooding.

Although the above summarizes the current thinking in regard to the influence of oil viscosity on secondary recovery, it is obvious that much field and laboratory research will be necessary to give an accurate picture. It has been shown that the thickness of the oil film retained on a mineral grain surface is directly proportional to the viscosity of the oil, other conditions being equal. Although this may not be comparable with conditions as they exist in the reservoir, in which the mineral grain may be encased in a film of water, it is at least indicative of the importance of viscosity to the residual oil content. Further evidence of the influence of viscosity, namely in its effect on fluid flow, indicates that if Darcy's law is to be accepted, the rate of flow will be inversely proportional to the viscosity of the oil. Thus, if the viscosity of the oil is doubled, either the imposed pressure gradient must be doubled or the number of injection and recovery wells must be increased to maintain the same rate of production, other conditions being equal. It is not known whether this relation between viscosity and fluid flow is valid in the case of multiphase flow of gas, water, and oil in the reservoir. However, there is one factor which should be considered in this connection. Viscosity is not a function of temperature alone, for the viscosity of a crude oil under reservoir conditions also varies with the amount of gas in solution in the oil. Since solubility increases with pressure up to the saturation point of the oil, and viscosity decreases with increased gas saturation, viscosity indirectly becomes a function of pressure. In flow towards the well, a resultant drop in pressure below the saturation point will occasion the release of gas and an increase in oil viscosity. Since most reservoir crude oils contain some gas in solution, viscosity is not a constant but increases in the direction of flow. This release of solution gas, which causes an increase in free gas saturation, also affects markedly relative permeability. Finally, the components and conditions necessary for the formation of a froth [68] are present in nearly all reservoirs, and chances are that most of the production in the vicinity of the well-bore is in the form of a foam. The viscosity of stable foams or froths is known to be much greater than that of the constituents alone which make up the froth.

---

[66] Op. cit., p. 204.

[67] Heath, W. A., Influence of viscosity of crude oil on secondary recovery: Am. Petroleum Inst. Prod. Bull. 230, pp. 171-176, 1943.

The chemical makeup of the oil phase may have some influence on its flow properties through a reservoir sand. The deposition of solid paraffin and asphaltic substances from the oil in tubing, casing, perforations, and formation pores about the well-bore has been the source of a great deal of difficulty. The sands adjacent to the well may become so plugged with this solid material as to seriously reduce their conductivity. Earlier work on deposition seems to indicate that it is a result of changes in temperature, pressure, and gas saturation within the reservoir. Preckshot and others [69] have attributed the deposition of asphaltic particles in reservoir sands to an electrical phenomenon. The flow of fluids through a reservoir sand may set up a potential referred to as the "streaming potential." The amount of potential is apparently dependent upon the rate of flow, size of the flow channels, and nature of the fluid flowing. This potential may cause the precipitation of colloidal asphalt particles by the process of electrodeposition. In experiments in which crude oil from the Greeley field in California was used, it was found that upon passing the crude through alumina cores, an appreciable potential was set up causing the precipitation of asphaltic particles.

The presence of polar impurities in crude petroleum has a marked influence on surface forces and displacement phenomena. It is known that polar compounds containing oxygen, sulphur, and nitrogen, some of which are acidic and others basic, do occur in many crude oils.[70] These compounds are usually surface active in that they consist of two parts, one similar in nature to water (polar), and the other similar to the crude oil (non-polar). The polar part, being hydrophilic, would be oriented towards the water phase at an oil-water interface, and the non-polar part, being hydrophobic, would be oriented toward the oil phase. Adsorption of these compounds at interfaces in the reservoir has an effect on surface and interfacial tensions. Gibbs has deduced that such substances will become positively adsorbed at the interface if in so doing, the boundary tension is reduced.[71] In analyzing this behavior in the reservoir, it can be readily understood that interfacial tension between the water and crude oil would be reduced by the presence of polar compounds. Likewise, polar compounds, when concentrated at a solid surface, so orient themselves as to make the normally hydrophilic surface become hydrophobic. Polar compounds would have little effect on oil-gas interfaces but they would affect water-gas tensions. Since water readily wets hydrophilic rock material, it may be deduced that polar compounds would have little tendency to concentrate at the interface. However, Benner and Bartell [72] point out that because these compounds may be either acidic or basic, they may have a marked influence on the interface. Basic polar impurities are chemisorbed on an acidic-silica surface, whereas acidic polar impurities are chemisorbed on basic-carbonate surfaces. It appears, therefore, that the presence of even minute quantities of polar impurities in crude oil can influence the wettability of reservoir sands and the resulting displacement phenomena.

---

[68] Somerton, W. H., Foaming tendency and stability of crude oil foams: Am. Petroleum Inst. Drilling and Production Practice, pp. 148-155, 1943.

[69] Preckshot, G. W., et al., Asphaltic substances in crude oils: Am. Inst. Min. Eng. Trans., vol. 15, pp. 188-205, 1943.

[70] Benner, F. C., and Bartell, F. E., The effect of polar impurities upon capillary and surface phenomena in petroleum production: Am. Petroleum Inst. Drilling and Production Practice, 1941, pp. 341-348.

[71] Benner, F. C., and Bartell, F. E., op. cit.

[72] Op. cit.

Water Phases

In any petroleum reservoir there may be several types of water present. For example, bottom and edge-water may differ considerably from the connate water present in the oil zones and the available injection water may differ from these two. The interactions between these different waters may be of considerable importance, for the precipitation of solid salts may disasterously plug the sand pores.

Connate Water. Probably the greatest influence of the connate water in the oil zone is in its effect on relative permeability relations. Dickey and Bossler [73] have stressed the fact that the presence of connate water in certain quantities may have a favorable influence on secondary recovery. A reservoir with 40 percent oil saturation and 60 percent gas will produce at a gas-oil ratio of 4000, which is just out of the economic range. For a reservoir in which the oil saturation is the same but there is a 20 percent water saturation and 40 percent gas saturation, the gas-oil ratio would be 300, well within the economic range. In the case of water injection, a somewhat similar, although not as favorable, situation would occur.

The presence of connate water is also important from the standpoint of displacement and residual oil saturation. Were no water present coating the grain surfaces and occupying the finer capillary spaces, the oil would be retained in these spaces and would be unrecoverable at normal displacement rates. This effect is probably more prevalent in laboratory experimentation where no account is taken of water content, than would be the case in field practice because of the almost universal presence of connate waters in actual reservoirs.

The amount and nature of the connate water is an uncontrollable and sometimes an unknown factor in water-flooding. Methods of determining connate water content are seemingly unreliable, but capillary pressure-saturation experiments and the ''restored state method'' [74] of determining water content have shed some light on minimum water content. This work shows the minimum water content, or irreducible water saturation, to be a function of the sand properties. There is a correlation of a sort between this value and permeability which holds for the same types of formations. In general, the greater the permeability, the less the minimum water saturation and the closer this minimum saturation occurs to the water-oil contact in the reservoir. This relation is but an approximation because of the difference in geometry of sands of the same permeability. Clay content has a strong bearing on minimum water saturation, for most clay minerals retain their original water content tenaciously. Thus, so-called ''dirty'' sands may have a large connate water content far above the main water-oil contact in the reservoir. Connate water saturation may range anywhere from 15 to 50 percent, depending upon the nature of the formation. As this is but a minimum value, many reservoirs undoubtedly have a higher connate water content than is generally realized.

---

[73] Dickey, P. A., and Bossler, R. B., Role of connate water in secondary recovery of oil; Am. Inst. Min. Eng. Trans., vol. 155, pp. 175-183, 1944.

[74] Bruce, W. A., and Welge, H. J., Restored-state method for determination of oil in place and connate water: Oil and Gas Jour., July 26, 1947, pp. 223-238.

It would be interesting to know what happens to this connate water content under the influence of the injection water. Russell, Morgan, and Muskat [75] in a series of experiments on the mobility of interstitial waters have concluded that connate water is actually displaced to a large degree by the flood water, rather than retained in the formation as the flood water sweeps past. This conclusion is verified in field experience by the observation that the first water produced with the oil as a result of water-flooding is definitely saline.[76] The mobility of connate water influences the displacement of oil and the swelling characteristics of clays within the formation. It is also important in coring with water-base muds, for high mobility of connate water may result in considerable reduction in saturation of the cores obtained.

Connate water generally has a high dissolved-salt content. It has been reported that in some cases, connate water may have a total concentration of solids nine times that of normal sea water,[77] or as high as 300,000 parts per million. There are, however, many exceptions due to dilutions by meteoric water at the time of deposition. One would expect such a high salt content to have an appreciable influence on clays present in the formation. Clay probably exists in the reservoir in a flocculated condition and would have little effect in reducing permeability. Were this saline water replaced by fresh injection water, serious swelling of the clay would occur.

Connate water may have, through long periods of geologic time, reacted with the hydrocarbons with which it is in contact. Sulphate reduction may take place with the formation of sulphides, which precipitate from solution and deposit in the pore spaces. This reaction would result in a partial plugging of the formation. Many potential edgewater drives are believed to be inactive because of this occurrence at the water-oil contact.

Injection Water. A reliable source of injection water is a very important consideration. Water must be available in sufficient quantities throughout the year; it should require a minimum of treatment; and its properties should not change appreciably from one season to another. Holbrook and Ellenberger [78] list and classify the possible sources of water as follows:

1. Surface waters—rivers, streams, lakes or ponds—generally require considerable treatment.
2. Springs—desirable, but generally insufficient capacity.
3. Fresh subsurface waters—generally desirable from the standpoint of quality and quantity.
4. Subsurface brines—constant quality, but require extensive treatment.

Another possible source might be ocean water in coastal fields.

---

[75] Russell, R. G., Morgan, F., and Muskat, M., Some experiments on the mobility of interstitial water: Am. Inst. Min. Eng. Trans., vol. 170, pp. 51-61, 1947.

[76] Riggs, C. H., Water-flooding of the McClosky limestone: Prod. Monthly, vol. 9, May 1945, pp. 12-18.

[77] Crawford, J. G., Waters of producing fields in the Rocky Mountain region: Am. Inst. Min. Eng. Petroleum Tech., May 1948.

[78] Holbrook, G. W., and Ellenberger, A. R., Source and purification of water supply: Am. Petroleum Inst. Supplement 2, Secondary Recovery in the United States, pp. 45-50, 1947.

Considerable has been written regarding the type and treatment of water to be used for injection purposes. Obviously, it is desirable to use a water which will permit the maximum injection rate with the lowest expenditure of energy. The water should be free from suspended solids; it must not contain chemical agents which will cause corrosion of pipes and equipment; it should be free from bacteria and algae which promote the precipitation of solid material; it must be of such a nature as to prevent the swelling of clays; and its dissolved solid content must not cause the precipitation of solid salts when in contact with formation water. Few naturally occurring waters meet these strict requirements and some treatment is generally necessary.

Water Treatment. The extent and type of water treatment necessary is, of course, dependent on many conditions. The nature of the water, the amount and type of clay, the nature of the connate water in the formation, and economic factors must all be considered. Waters may be treated from two standpoints: (1) to prevent plugging and corrosion; and (2) to increase the ability of the water to displace oil.

Suspended material in the water, such as silt, clay, and vegetation, must be removed to prevent plugging of the formation around the bore of the injection well. This may be accomplished by a variety of filtration and settling methods. Great care must be taken to remove the very finest of suspended material, for it is only the fine particles which can enter the pores of the formation and effectively plug it.

Dissolved gases in the injection water (oxygen, carbon dioxide, and hydrogen sulphide) are very detrimental corrosive agents and must be removed or their effects minimized. These gases in combination with water may cause serious deterioration of equipment and may also form insoluble precipitates which will tend to plug the formation. Aeration of the water is effective in removing carbon dioxide and hydrogen sulphide and also aids in the oxidation of iron and magnesium, the products of which may be removed by filtration. Aeration, however, may be objectionable because it increases the oxygen content of the water. Oxygen can be removed by the use of sodium sulphite, but such treatment is rather costly. Alkalis may be used to remove carbon dioxide, but careful control must be exercised because of the danger of continued precipitation and plugging of the sands. It has also been suggested that heating of the injection water would be effective in removing dissolved gases, notably hydrogen sulphide.[79]

Injection water may be thoroughly aerated to precipitate unstable iron, magnesium, and calcium compounds, but chlorine may also be used for this same purpose. Calcium hydroxide and aluminum sulphate may be added to aid in flocculating and settling out precipitates.[80] It is important, of course, that the water be stabilized before passing through the filter because, if it is not, precipitation may continue after injection.

Consideration must also be given to the possibilities of chemical reactions between injection and formation water which may result in the deposition of plugging precipitates. There are several possible cases where this can occur.[81] Amorphous silica is precipitated from alkaline solutions by carbon dioxide or by organic acids present in petroleum. Insoluble calcium sulphate may be precipitated when waters containing calcium chloride in solution are mixed with waters containing sulphates. Barium sulphate may be precipitated from barium chloride in a similar manner. Iron salts in acid or neutral solutions may precipitate as hydroxides if the solution becomes basic. The precipitation of insoluble carbonates may result when soluble calcium salts are brought into contact with soluble carbonates or when waters are changed from acidic to basic. These and other reactions with resultant clogging of pores can occur unless care is taken in the selection and proper treatment of injection waters.

---

[79] Plummer, F. B., Merkt, E. E., Power, H. J., et al., Effect of micro-organisms on the injection of water into sand: Am. Inst. Min. Eng. Petroleum Tech., January 1944.

[80] Plummer, F. B., and Walling, I. W., Laboratory investigations of chemical changes in east Texas oil-field water affecting its injection into subsurface sands: Am. Inst. Min. Eng. Trans., vol. 165, pp. 64-77, 1946.

Most water contains microscopic organisms (algae, bacteria, molds, and slime) which may themselves cause plugging of the sands and may also promote the precipitation of insoluble residue with similar results. Plummer [82] has investigated waters of the East Texas field and found them to contain four types of organisms believed to be harmful in the formation of precipitates. These have been identified as iron bacteria *(Gallionella, Leptothrix,* and others), sulphur-oxidizing bacteria *(Beggiatoa, Chromatium,* and others), sulphate-reducing bacteria *(Vibrio spp.),* and blue-green algae *(Oscillatoriaceae).*

Iron bacteria thrive in cold, slightly acidic water containing ferrous compounds. In their life process, they convert the ferrous compounds to gelatinous precipitates of ferric hydroxide which are effective in seriously clogging the pores of the oil sand. It has been found that this precipitate can be removed readily by filtration before the water is injected and that such material as reaches the sand face can be removed by acid treatment. The use of bactericides, aeration to remove iron, and heating of the water are generally effective in the removal of iron bacteria.

Sulphur-oxidizing bacteria are very common in waters containing hydrogen sulphide. There are several varieties of this type, some of which accumulate sulphur within their cells. Others produce free sulphur, and still others react with free sulphur to produce sulphuric acid. The types which accumulate sulphur within their cells are the most difficult to remove. The sulphuric acid produced by the last type is neutralized by calcium carbonate and bicarbonate in the water, forming calcium sulphate. Where carbonates are not present in the water, the acid reacts with the iron of pipes and tanks to produce soluble ferrous sulphate. This in turn may react with hydrogen sulphide to form a precipitate of ferric sulphide.

Sulphate-reducing bacteria thrive in fresh, brackish, and salt water containing sulphates and some organic material which is apparently necessary for their growth. The hydrogen sulphide produced by these bacteria reacts with dissolved metallic salts in the water to form sulphide precipitates.

From the standpoint of corrosion and plugging, sulphur bacteria are undesirable in injection waters and should be destroyed or inhibited by proper treatment. Plummer [83] states that the use of bactericides properly injected into water systems, and frequent aeration and oxidation of the substances which accelerate bacterial growth, will greatly reduce the formation of hydrogen sulphide by sulphate reduction.

---

[81] Uren, L. C., op. cit. (1939).

Andresen, K. H., and Heck, E. T., Effect of properties of flood water on rate of input and oil production: Am. Petroleum Inst. Drilling and Production Practice 1946, pp. 236-243.

[82] Plummer, F. B., et al., op. cit. (1944).

[83] Plummer, F. B., and Walling, I. W., op. cit.

Algae are abundant in warm oil-field waters. These algae have the ability, in sunlight, to take CO_2 from water containing bicarbonates, and deposit calcium carbonate in the form of a white precipitate which collects on and under the algae mass. Sulphur-producing bacteria are often associated with algae and the resultant sulphur and calcium carbonate deposition is very effective in plugging pores. The proper use of bactericides and subsequent filtering of the water will remove the algae and their precipitates.

Actually there is too little known regarding the influence microscopic organisms may have on water injection. It is doubtful that all such organisms are harmful. In fact, there is evidence that certain types of bacteria may be beneficial; but until more is learned of their activities, treating methods will probably dictate as complete a removal of bacteria as is economically feasible. There is a question as to how important these organisms are in the formation of precipitates and corrosive agents which could have been formed by chemical action alone. They may act as catalysts in promoting chemical changes but here again, clays suspended in the water may serve a similar function.

The pH value of injection water is important from the standpoint of corrosion, clay swelling, and precipitation of carbonates. It has been the practice in the past to keep the pH value of the water slightly on the alkaline side to minimize corrosion. The use of alkalis to raise pH, however, can readily cause the precipitation of carbonates. Certain polyphosphates have been successfully used in raising pH, and yet they retain the carbonates in solution. Research by Breston and Johnson [84] however, shows that the conductivity of certain sands increased greatly upon changing from fresh water to water with pH values of from 3 to 5. Andresen and Heck [85] state that a base-exchange reaction in certain types of clays, where sodium is replaced by hydrogen ions, might be desirable, for the presence of hydrogen ions in the lattice of most clays causes a delay or prevention of incorporation of water into the clay micelles. The farther the removal of the pH value from the isoelectric point of the clay, the greater is the swelling. Since the isoelectric point of clay colloids is normally well on the acidic side, this should dictate the use of low pH flood water to minimize swelling. Thus, a low pH flood water would be of advantage both from the standpoint of preventing precipitation of carbonates and also of reducing clay swelling. Corrosion by low pH water can be prevented by the use of proper inhibitors. Breston and Barton [86] conducted a series of tests using rosin-amine acetate in concentrations of but a few parts per million and found it to be effective as a corrosion inhibitor as well as an aid in reducing bacterial action.

It can be seen from the above discussion that what might be considered the ideal treatment of injection waters may become very complex and economically prohibitive. A more logical approach to the subject has been taken by Hughes and Pfister[87] in their paper proposing the use of brines rather than fresh water for injection purposes. They point out that fresh water treated by the most scientific methods for the control of corrosion and organic growths, removal of harmful suspended and dissolved materials and with an artificial high pH value, very often shows declining injectivity in actual practice. On the other hand, the injection of produced brines has resulted in uniform and even increasing injection rates in many cases. Their point is well taken for nature very effectively displaces oil with brines.

---

[84] Breston, J. N., and Johnson, W. E., Effect of pH on water intake rates of oil sands: Prod. Monthly, vol. 9, no. 12, pp. 19-23, October 1945.

[85] Andresen, K. H., and Heck, E. T., Effect of properties of flood water on rate of input and oil production: Am. Petroleum Inst. Drilling and Production Practice, 1946, pp. 236-243.

[86] Breston, J. N., and Barton, K., Field test of corrosion inhibitor for low pH flood water: Prod. Monthly, vol. 12, no. 1, pp. 13-17, November 1947.

It has been stated[88] that the best possible water for injection purposes is that produced from the same zone which is to be flooded. This statement can be justified from several standpoints. Obviously the injection of the water that is produced from the same formation will eliminate reactions between dissimilar waters and possible resultant precipitation. A clay is generally permeable to water which has characteristics similar to that with which it is saturated. Even though the clay may occur in the reservoir in a somewhat swollen condition, the fact that the brine was producible indicates that the clay must be permeable to that particular brine. Experiments have shown[89] that even when the produced brine is diluted with fresh water to increase the total amount of water available for injection, it is still a desirable flood water.

The second best source of flood water is brine obtained from other zones with a chemical makeup similar to that occurring in the zone to be flooded. Added treating expense may be involved in improving its characteristics but it will undoubtedly be cheaper and more effective than other available waters.

The third choice would be a brine artificially prepared from fresh water. This would involve considerable expense and great care would be necessary to produce a truly stable brine.

Produced brines should be no more corrosive than fresh waters if they are kept free from oxygen or are properly de-aerated. Many operators injecting produced brines employ a closed system whereby air cannot contact the water at any time. Produced brines generally have a pH value between 7.5 and 6.5. Although a minimum of treatment is preferable in using produced brines, careful use of bactericides, corrosion inhibitors, and mild acid to lower pH, may improve the injection properties.

Injection water may also be treated from the standpoint of improving its displacing ability. Early attempts were made to improve displacement efficiency by the soda-ash treatment. Laboratory tests showed rather conclusively that sodium carbonate added to the injection water even in small concentrations very effectively removed adherent oil films from mineral-grain surfaces. This is to be expected in considering the interfacial tension relations effective in the reservoir. Sodium carbonate reduces the tension between both water and oil and water and mineral-grain surface, resulting in complete displacement of the oil. In actual practice, the process was unsuccessful for two reasons.[90] It proved impossible to maintain the sodium carbonate concentration at a sufficient distance from the well to be effective. The formation of insoluble precipitates resulted in serious plugging of the pores and greatly decreased water input rates. Although there are probably other substances which could be employed for this purpose which would not form harmful precipitates, the fact that the surface-active substance must be adsorbed at the interfaces to reduce tension would lead to the difficulty of ever maintaining sufficient concentration in the advancing water.

---

[87] Hughes, R. V., and Pfister, R. J., Advantages of brines in secondary recovery of petroleum by water-flooding: Am. Inst. Min. Eng. Trans., vol. 170, pp. 187-201, 1947.

[88] Hughes, R. V., and Pfister, R. J., op. cit.

[89] Hughes, R. V., and Pfister, R. J., op. cit.

[90] Uren, L. C., op. cit. (1939).

The work of ZoBell and associates [91] has shown that certain sulphate-reducing and possibly other anaerobic bacteria have the ability to release oil from the mineral-grain surfaces. There are at least three means by which these bacteria release hydrocarbons from grain surfaces and they are important in explaining the migration and accumulation of petroleum and its displacement in production. Certain of these bacteria dissolve carbonates in the reservoir and in so doing release the adherent oil. This dissolution also results in the formation of carbon-dioxide gas which aids recovery by decreasing oil viscosity and increasing reservoir pressure. Certain other bacteria, having a strong affinity for solid surfaces, may physically displace the oil by crowding it off the grain surfaces. Other bacteria produce detergents or surface-active substances which reduce interfacial tensions to the extent that oil is readily displaced.

Just how important these bacterial actions may be in water-flooding is not thoroughly understood. If it were possible to load the injection water with these bacteria, neutralize any undesirable effect they may have, and provide conditions to encourage their rapid growth, highly effective displacement might result. Even if their activity of producing surface-active substances were alone considered, they would have a decided advantage over chemical additives, in that they have the ability of multiplying rapidly and maintaining concentration. Probably the greatest question is that of time. There is little indication as to whether the above reactions are only of importance in terms of geologic time or whether they are sufficiently rapid to be of importance in the normal period of production.

One additional characteristic of injection water should be mentioned before leaving the subject. It has been stated [92] that the use of brines for injection might be objectionable from the standpoint of increased viscosity. The viscosity of water is increased considerably with increase in dissolved salt content and it requires a higher pressure to move the water through the reservoir. This is a valid objection where low-viscosity crude oils are being recovered. However, when the viscosity ratio reaches a certain maximum value, instability of the interface and water bypassing become much more important considerations than pressure required to inject water. Where heavier, more viscous crudes are to be recovered by water drive, the greater viscosity of brines will decrease the viscosity ratio and increase displacement efficiency. It has been suggested that water-flooding of heavy California crudes might only be possible when methods of effectively increasing the viscosity of injection waters are discovered.

---

[91] ZoBell, C. E., Functions of bacteria in the formation and accumulation of petroleum: Am. Petroleum Inst., Rept. of Progress on Fundamental Research, pp. 73-78, 1944-45.

[92] Andresen, K. H., and Heck, E. T., op. cit.

Correlation to California Conditions

Essentially all of California's crude oil is of asphaltic base. Low-gravity and high-viscosity oils are characteristic in most fields which might be considered for water-flooding. The few exceptions are generally found in the deeper fields or zones. The selling price of California crude is somewhat greater than its characteristics might indicate, primarily because of the large demand and limited supply.

There is little information available regarding the impurities present in the crude oil which might cause plugging by precipitation or might alter surface tension relations. Investigations of California crude-oil foams indicated the presence of sufficient surface-active agents to promote very stable foams.[93] In addition, the precipitation of paraffin and asphaltic substances in wells is so common as to make this a matter of some importance. Analysis of crude oils and laboratory flooding tests will be necessary to determine the influence of these impurities (polar or otherwise) on water-flooding.

Most California reservoirs are known to contain an appreciable amount of connate water. Capillary pressure curves generally substantiate this observation. However, a high clay content usually results in a high residual water saturation as determined by capillary pressure methods. A high clay content may effectively remove large amounts of connate water from the system so that there may be insufficient free water present to encase the mineral-grain surfaces. In such cases the grain surfaces will be coated with oil and subsequent adsorption may make these surfaces permanently hydrophobic.

Sources of injection water may be a major problem in water-flooding California oil fields. It is almost a certainty that fresh surface waters will not be available for injection purposes, for the water-table has been dropping steadily throughout most of the state for the past several years. In addition, many of the fields are located in arid or semi-arid regions where water supplies have always been a problem. This indicates that sub-surface brines will have to be employed for injection purposes. Many fields located in agricultural areas have serious waste water disposal problems. The controlled reinjection of this water may solve disposal problems and produce a beneficial water-flooding effect.

The possible use of ocean water in coastal areas should be investigated. This would provide an unlimited supply of water with constant characteristics. Its saline properties may be such as to make it a desirable flooding water.

No general statement can be made regarding the feasibility of water-flooding in California from the standpoint of the reservoir fluids without considerable qualification. The properties of the oil from the consideration of selling price, gravity, and viscosity, place it definitely on the borderline. There is also a question as to the availability of injection water, but no conclusion can be reached without further investigation.

Fluid Saturation

The most important single factor to be considered in water-flooding is the fluid saturation of the reservoir and, in particular, the oil saturation. Both the total amount of recoverable oil and the percent oil saturation are important. Frequently there is encountered in the literature the term "total oil content in barrels per acre foot." It must be understood at the outset that this term is meaningless as far as estimates of recovery are concerned. Modified to "recoverable oil per acre-foot" it takes on a good deal of significance, for this is the principal factor which must be known in determining the feasibility of water-flooding. Its importance is demonstrated by an example given by Dickey.[94] A total oil content of 500 barrels per acre-foot in a sand of 25 percent porosity would give an oil saturation of 26 percent. On the other hand, were the total oil content the same but the porosity of the sand only 15 percent, the oil saturation would be 43 percent. At a residual saturation of 25 percent, no appreciable oil could be recovered from the first sand, whereas 210 barrels per acre-foot could be recovered from the second sand. It is therefore very important to know the percent of the void space occupied by the oil.

---

[93] Somerton, W. H., op. cit.

Saturation from Core Analysis

Before continuing the discussion of the effect of fluid saturation on water-flooding, it would be well to review the methods by which saturation may be determined and to consider the accuracy of these methods. Present methods of determining fluid saturation of a reservoir sand are not wholly satisfactory. For example, the most common method, analysis of core samples obtained in drilling through the formation, does not give true reservoir-saturation data. Flushing action of the drilling fluid and the escape of gas resulting from pressure reduction as the core sample is withdrawn at the surface, are both effective in altering the saturation of the core.

The loss of fluids from a core sample by the expansion of gas has a pronounced influence on the ultimate saturation of the core. The action is similar to that occurring in fluid expulsion from a reservoir by gas expansion except that in this case the pressure differential is greater and the loss of fluids correspondingly greater. Loss of fluids due to this cause can be reduced to a negligible amount through the use of pressure core barrels. Johnston,[95] Mullane,[96] and others have adequately discussed the use and advantages of pressure-coring techniques. The prime function of the several types of core barrels is to seal the core sample at the same pressure at which it existed in the formation. When the sample is retrieved at the surface, the pressure is carefully reduced, the amount of gas measured, and the liquid content as it existed in the core prior to its removal to the surface can be determined. Mullane [97] reports that in addition to liquid saturations, by this method reasonably reliable gas-oil ratios may also be determined.

The pressure core barrel only partially solves the problem of deducing reservoir saturation from core analysis, the most difficult problem being that of flushing by the drilling fluid. The mechanism by which cores are flushed by drilling fluid is similar to the action of encroaching edgewater or a water-flood in depleting the reservoir. Earlougher [98] has noted that cores from primarily depleted sands undergo less oil flushing than those taken from virgin reservoirs where the liquid saturation is high. He explains this on the basis of permeability-saturation relations in which the high oil saturation of the virgin reservoir permits rapid desaturation of the oil from the core. In depleted reservoirs the low oil saturation results in a low permeability to oil and a decrease in the rate and ease of desaturation of the core. The factors which seem to have the greatest influence on flushing are time required to take the core; permeability, porosity and diameter of the core; nature of the drilling fluid (in particular its wall-building characteristics); viscosity of the oil; and the original fluid saturations. Attempts have been made to correlate these characteristics to residual saturation in deducing reservoir saturation but they have met with only limited success. A correlation of a sort may be obtained in areas where reservoir characteristics are similar. At best it is believed that the oil remaining in the core after it has been subjected to the flushing action of the drilling fluid may represent a close approximation to the minimum residual saturation to be expected after water-flooding of the sands.

---

[94] Op. cit.

[95] Johnston, N., Core analysis interpretation: Am. Petroleum Inst. Drilling and Production Practice, 1941, pp. 180-199.

[96] Mullane, J. J., Pressure core analysis: Am. Petroleum Inst. Drilling and Production Practice, 1941, pp. 163-179.

[97] Op. cit.

[98] Earlougher, R. C., Core analysis problems in the mid-continent area: Am. Petroleum Inst. Prod. Bull. 230, pp. 323-326, 1943.

In cases where filtrate from the drilling fluid has been added to the core without displacement or flushing of the connate water, the connate-water saturation may be deduced from the chloride concentration of the resulting water mixture, if the chloride concentration of the connate water in the formation is known. However, Russell and others [99] have shown that connate water may have considerable mobility, and they have deduced that connate water is often displaced by the filtrate. Another objection to this method lies in the fact that diffusion to the drilling fluid of a part of the salt content of the core probably occurs.

The use of tracers in the drilling fluid has been partially successful in determining the contamination of cores. Inaccuracies due to diffusion may be eliminated by this means, but flushing still undoubtedly occurs. Both of these methods will usually give a lower connate-water content than that which occurs in the reservoir.

The use of oil-base muds in coring productive formations has been of considerable aid in deducing connate water content. Russell [100] states that ''the inherent lack of mobility of conate water during normal clean oil production indicates that there is little likelihood of connate water displacement by invasion of oil when coring with oil.'' It is apparent that this would be the case when the water saturation is below a certain maximum as determined by relative-permeability-saturation relations. However, deceiving results might be obtained in cases where the water saturation is above this maximum value.

It can be seen that the analysis of cores in determining fluid content may be very useful in predicting the minimum residual oil saturation after water-flooding. It is probable, however, that this value could be deduced as readily by laboratory flooding tests. Another important value of core analysis is the determination of connate water saturation from oil-base cores. With this information at hand it is possible to estimate reservoir oil saturation by volumetric-balance calculations.

---

[99] Russell, Morgan, and Muskat, op. cit.
[100] Russell, Morgan, and Muskat, op. cit.

Fluid Saturation by Restored-State Method

A relatively new method[101] of deducing connate-water content is based on capillary phenomena. This method assumes that the reservoir is in capillary equilibrium, that is, the fluids are distributed in the reservoir sands in accordance with their capillary behavior. In the original processes of migration and accumulation oil, by virtue of its lesser density, replaced a portion of the water in formations which were originally completely saturated with water. However, because of the greater capillary attraction of the water, oil was unable to replace all the water; the portion retained in the sand is known as connate water. The restored state method is based on essentially the same principle, but on a laboratory scale. A carefully prepared core specimen is saturated with the same water with which it was saturated in the reservoir. The core is then placed in a chamber on a semi-permeable membrane (permeable only to water) and oil pressure is applied. As the pressure is increased, the oil displaces more and more water up to a certain maximum pressure where further increase does not cause additional displacement. Records may be kept of the amount of displacement and a graph of ''capillary pressure'' versus water saturation plotted. By use of the above graph and certain theoretical relations to be discussed later, it is possible to deduce the water saturation at any height in the reservoir above the level of zero oil saturation. The minimum water saturation obtained is considered to be the irreducible water saturation of the core.

This method should give a fairly reliable value of the minimum water content and water distribution as a function of height above the level of zero oil saturation in a virgin reservoir. Obviously, the method could not be relied upon in the case of a partially depleted reservoir for, in this case, capillary equilibrium does not exist. The work of Bruce and Welge[102] shows a reasonably good agreement between the results obtained by the restored-state method and other common methods of determining water content.

That this method could not be relied upon in all cases may be deduced from statements made by Ryder.[103] It has been held by many that in certain reservoirs the sands are oil wet because of their very low connate water content. Ryder explains this as due to gas preceding the oil in displacement of water from the reservoir. Earlier work by Russell[104] has shown that water saturation in soils can be reduced to nearly zero when air is the displacing medium. It has been noted that some reservoirs have an exceedingly high salt content and that salt crystals occasionally are found in the sands. This has probably resulted from evaporation of part of the water originally in the sands. Ryder[105] deduces that gas may effectively reduce the water saturation to near zero by its superior displacing ability and by evaporation effects. Therefore it seems plausible that the water content of some reservoirs may be less than that predicted by capillary-pressure determinations. Capillary theory would also dictate that at some capillary pressure, the residual water saturation should approach zero. Except for the case cited eariler, this has not been found so in the laboratory, at least within the range of pressures encountered in petroleum reservoirs.

---

[101] Bruce, W. A., and Welge, H. J., Restored-state method for determination of oil in place and connate water: Oil and Gas Jour., July 26, 1947, pp. 223-238.

Thornton, O. F., and Marshall, D. L., Estimating interstitial water by the capillary pressure method: Am. Inst. Min. Eng. Trans., vol. 170, pp. 69-80, 1947.

[102] Op. cit.

[103] Ryder, H. M., Character of pores in oil sand: World Oil, April 1948, pp. 129-134.

[104] Russell, M. B., Soil moisture sorption curves for four Iowa soils: Soil Sci. Soc. America Proc., vol. 4, no. 51, 1939.

[105] Ryder, H. M., Character of pores in oil sand: World Oil, April 1948, pp. 129-134.

Saturation from Electrical Logs

The ability to determine qualitatively the fluid saturation of a sand by electrical resistivity has long been recognized.[106] The use of electrical resistivity for quantitative determinations of fluid content in laboratory experimentation has been demonstrated by Wyckoff and Botset,[107] Leverett [108] and others. Archie [109] has applied this same principle to the quantitative determination of the saturation of reservoir formations from electrical logs. In measuring saturation as a function of resistivity, the following relation has been found to hold true approximately:

$$S = \left[\frac{R_0}{R}\right]^{\frac{1}{n}} \text{ or } R = R_0 S^{-n}$$

where: S = percent water saturation
R = resistivity of sand with water saturation S.
R_0 = resistivity of same sand at 100 percent water saturation.

For clean unconsolidated sand and consolidated sand, the value of "n" is close to 2, so that:

$$S = \sqrt{\frac{R_0}{R}}$$

These relations appear to be valid in the laboratory for water saturations down to about 15 to 20 percent. Considering the infinite number of possible arrangements of water distribution in the pores, there is some question as to why this relation should hold. However, there is found to be no great change in resistivity, regardless of the nature of the water distribution and whether the non-conducting phase be oil or gas.[110] The lower limit of applicability of this relation probably occurs when the water saturation passes from pendular to funicular, that is, when the water phase ceases to be continuous throughout the sand.

The values of R and R_0 are usually obtainable from the electrical log, but not directly so. Variables such as diameter of the hole, electrode spacing and bed thickness, resistivity and penetration of the drilling fluid, must be known and properly evaluated to obtain true resistivity values. With these considerations in mind, R can be determined for the formation concerned and R_0 may be determined from sands in the same horizon which are completely saturated with formation water. This latter value could also be obtained from laboratory tests on cores resaturated with the original formation water. A basic assumption made is that the salinity of the connate and formation water is the same throughout the horizon.

---

[106] Schlumberger, C., and Leonardon, E., Electrical coring—a method of determining bottom-hole data by electrical measurements: Am. Inst. Min. Eng., vol. 110, pp. 237-289, 1934.

[107] Wyckoff, R. D., and Botset, H. G., op. cit.

[108] Leverett, M. C., Flow of oil-water mixtures through unconsolidated sands: Am. Inst. Min. Eng. Trans., vol. 132, pp. 149-169, 1939.

[109] Archie, G. E., The electrical resistivity log as an aid in determining some reservoir characteristics: Am. Inst. Min. Eng. Trans., vol. 146, pp. 54-62, 1942.

[110] Archie, G. E., op. cit.

Since the resistivity scale used on electrical logs assumes the electrodes to be points in a homogeneous bed,[111] corrections must be applied for the diameter of the bore-hole and thickness of the beds relative to the electrode spacing. If the resistivity of the drilling mud is the same as that of the formation, no correction need be made for the hole size. Where this is not the case, tables have been derived from experimental work whereby a correction can be applied to measured resistivity values for various mud resistivities and hole sizes. Again, where the thickness of the bed is large relative to the electrode spacing, no correction for bed thickness is necessary. For bed thicknesses approaching electrode spacing, a correction must be applied from experimental data.

The above relations assume uniform sand conditions (porosity, permeability, etc.) and limited invasion of drilling fluid filtrate. If these conditions do not apply, it may be difficult to deduce true resistivity from log records. Archie [112] considers invasion to have the most pronounced effect but indicates that it can be minimized by conditioning the mud fluid for low water-loss.

Great progress has been made in recent years in the interpretation of electrical logs, and it appears that the large number of such logs available will be of great help in determining water content where core data are questionable or unavailable. In the use of electrical logs for water-saturation determinations, a good deal of calibration data from actual cores and from laboratory experimentation will be necessary.

Calculations of Total and Recoverable Oil

A combination of the above methods is generally necessary in the calculation of reservoir fluid content, for obviously no one method will give all the desired quantities. If in a virgin reservoir the connate-water content can be determined with a fair degree of assurance and properties of the hydrocarbons (solubility, gas-oil ratio, formation-volume-factor) and reservoir pressure and temperature are known, it is a relatively simple matter to calculate the oil in place. These calculations will assume equilibrium conditions, which assumption should be valid for a virgin reservoir. With this information and a knowledge of reservoir porosity at hand, relative fluid saturations may be calculated.

Calculation of fluid content of partially depleted reservoirs is a much more difficult problem except in certain cases where core analysis data are reliable. Dickey [113] cites but three examples where this is the case: Bradford, Venango, and the Bartlesville sands of northern Oklahoma. In these areas, it appears that flushing of cores is either negligible or so consistently uniform that fluid saturation can be readily deduced. This can be attributed mainly to the low permeabilities and low pressures common to these areas.

---

[111] Schlumberger, C., and Leonardon, E., op. cit.
[112] Op. cit.
[113] Op. cit.

In all other cases of depleted fields, much more approximate methods are necessary. Again, it should be possible to determine water content of the sands with fair accuracy and if bottom-hole samples are available, volumetric-balance calculations should yield a reasonable value of oil in place. Dickey [114] also stresses the importance of the past production history of a well or group of wells as a guide in calculating reservoir oil content. If enough is known regarding edgewater encroachment, location and extent of gas cap, and the production history of the field or zone within the field, volumetric-withdrawal balance calculations will yield a good guess of oil content. Higgins' [115] method of estimating fluid content from productivity index might also be a valuable adjunct to this work.

It is important to consider both vertical and lateral variation in fluid content of a sand. Dickey [116] indicates that in areas where water-flooding has been practiced the most, this is not an important consideration. In California, however, the characteristic non-uniformity of reservoir sands has probably resulted in non-uniformity of fluid distribution. The original water content may vary from one portion of a field to another because of differences in sand characteristics (mainly permeability and clay content). Lateral variation in water content may also result from bypassing and non-uniform encroachment of edgewater and the flooding of certain areas by faulty formation shut-offs in some of the wells.

Vertical variation in water content is very pronounced. Sand layers completely saturated with water are commonly interbedded with others almost devoid of water. In practice it is necessary to attempt to isolate each zone and perform individual fluid-content determinations. In the completion practice or flooding project only those zones with favorable fluid saturation would be considered, all other zones being blanked or sealed off.

A reliable value of porosity is very important in determining percent saturations. Saturation expressed in terms of percentage of void space occupied by the fluid is the only value of importance in permeability-saturation relations. For this purpose, it is important to determine the porosity of the same core specimen used to measure saturation. An average or mean value of saturation can then be employed in predicting flow characteristics. However, in estimating reserves, it is probably more expedient to express saturation in terms of bulk sand volume. It thus becomes unnecessary to be concerned with porosity or porosity variations directly.

Influence of Saturation on Flow and Recovery Characteristics

The effect of saturation on fluid flow has been recognized to be so important as to deserve considerable discussion. Wyckoff and Botset [117] first showed the relations that exist between relative permeability and saturation in the simultaneous flow of gas and liquid through sands. Similar work has been performed with oil and water [118] and with three phases [119] (gas, oil, and water), all showing that the permeability of the sand to any one phase depends on the saturation of that phase. Curves obtained by different experimenters using different sands are of the same general shape and type but are displaced in one direction or the other. This may be the result of different experimental techniques, especially in determining saturation, but it can also be explained on the basis of surface and capillary effects. In this latter respect, one might expect a difference between consolidated and unconsolidated sands, and fine- and coarse-grained sands. The nature of the liquids and gases, and the clay content of the sand would also have a bearing on permeability-saturation curves.

---

[114] Op. cit.

[115] Higgins, R. V., Productivity of wells and inherent influence of gas-oil ratios and water saturation: U. S. Bur. Mines Rept. Inv. 3657, 1942.

[116] Op. cit.

[117] Op. cit.

[118] Leverett, M. C., Flow of oil-water mixtures through unconsolidated sands: Am. Inst. Min. Eng. Trans., vol. 132, pp. 149-169, 1939.

[119] Leverett, M. C., and Lewis, W. B., Steady flow of gas-oil-water mixtures through unconsolidated sands: Am. Inst. Min. Eng. Trans., vol. 142, pp. 107-116, 1941.

As is the case with all fluids, there is an oil saturation below which practically no oil will flow. Although this minimum value varies somewhat, 20 percent is a safe average value.[120] The water-oil steady-state flow ratio at any given water saturation may be calculated from the following relation:

$$\frac{V_w}{V_o} = \frac{K_w \mu_o}{K_o \mu_w}$$

The work of Leverett and Lewis[121] has shown that for oil saturations between 20 and 30 percent, the flowing water-oil ratio is about 10 and that for oil saturations between 60 and 70 percent, the ratio is about 0.10. For water saturations between 40 and 55 percent and for corresponding oil saturations between 30 and 45 percent, considerable quantities of both liquids are present in the flowing stream. There is a rather narrow range of saturations where all three fluids flow simultaneously in appreciable quantities. These are: 40 to 60 percent water, 25 to 45 percent oil, and 15 to 30 percent gas. Whenever these values are exceeded by any one fluid, the flow will be predominantly of that fluid.

Buckley and Leverett[122] have explained that the displacement of oil by water occurs in two stages. In the "initial" stage, due to the fact that permeability to the oil is greater than to water (because of the higher oil saturation), a bank of oil is built up ahead of the water and expelled by a shoving or piston action. The second, "subordinate", stage occurs when the oil bank has passed and additional oil is expelled only by frictional or shearing action. This subordinate stage is highly ineffective. If the oil saturation is so low as to form no bank, recovery of oil will be very limited. This two-stage process probably occurs in the Bradford area but is masked by the fact that beds of higher permeability may be in the subordinate stage and producing mostly water while other less permeable beds in the same horizon may still be in the initial stage of displacement.[123] Thus wells in this area go to water at a slow rate rather than a rapid rate as would be the case in a homogeneous horizon. The significance of this discussion lies in the fact that if the oil saturation is below a certain value, no initial stage of displacement will occur and water-flooding will not be successful.

From fluid-saturation determinations it is possible to predict the success of secondary recovery and to determine whether water-flooding or gas-drive would be more successful. For example, if the gas saturation is high, say 30 percent or higher, but oil and water saturations are about equal, gas-driving would not be successful but water-flooding might prove to be so. On the other hand, if the water saturation is relatively high but gas saturation is low, gas-drive should prove effective whereas water-flooding would not be successful. Dickey and Bossler[124] give as an example of this the Bradford and Venango fields of Pennsylvania. In the Bradford field, the average oil saturation is about 40 percent and the average water saturation 30 percent. Early attempts at gas-driving were unsuccessful but water-flooding has been outstandingly successful. In contrast, the Venango field with an oil saturation between 25 and 35 percent and a water saturation of 40 to 60 percent, is an example of a successful gas-drive field where attempts to water-flood were failures. It would appear that relative saturations are quite critical and that their effects are probably a good deal more pronounced than those of viscosity and capillary phenomena.

---

[120] Dickey, P. A., op. cit.
[121] Op. cit.
[122] Buckley, S. E., and Leverett, M. C., Mechanism of fluid displacement in sands: Am. Inst. Min. Eng. Trans., vol. 146, pp. 107-116, 1942.
[123] Dickey, P. A., and Bossler, R. B., op. cit.

Summary and Correlation to California Conditions

Although methods of measuring fluid saturations are not wholly satisfactory, data from core samples, laboratory experimentation and electrical logs should give reasonably reliable values. A good deal of laboratory and field research will be necessary to completely solve this problem, if a complete solution is possible.

A large amount of the recent coring in California has been done with oil-base muds. In addition, many of the oil companies include capillary-pressure-saturation measurements as a part of routine core analysis. This will give valuable information on the fields concerned. In addition, correlation of these data with other physical characteristics of the reservoirs may make it possible to deduce the characteristics of older fields where such data are meager or entirely lacking.

From information presented in the literature, it appears that interstitial water content of many California reservoirs is quite high. Values of 35 to 45 percent are common. This is perhaps a result of the high clay content, fine grain size, and low permeability of many of the reservoir sands. Although there is much to be learned regarding its distribution, this high water content would perhaps be an additional limiting factor in water-flooding California fields.

It will be difficult to obtain adequate saturation data on the older fields in which core analysis and electrical logs are not available. What little data may be available will have to be employed in conjunction with production records. Some information may be obtained from deep-test wells drilled subsequent to the development of shallower zones. The value of such data should be realized in future deep drilling in older fields. Unfortunately, however, such meager data as may be available at the present time and may be obtained in future operations, may give misleading results because of the characteristic non-uniformity of California sands. For example, it is probable that water saturation varies widely throughout any one zone and unless many determinations have been made, it will be difficult to deduce a reliable average or mean value.

Residual oil saturations of California sands, after primary production, have been reported as being high because low recovery efficiency is common. The difficulties of directly measuring oil saturation already have been discussed, and it appears that absolute verification of the above statement must be deferred pending the development of more direct methods of measurement.

---

[124] Op. cit.

Capillary and Surface Effects

The importance of capillary and surface effects in the displacement of oil by water has been demonstrated. These forces are dependent upon many factors: mineral content and physical characteristics of the reservoir sands, nature and distribution of the reservoir fluids, and past history of the reservoir as a whole. It is the purpose of this section to gather together the frequent references to capillary and surface effects and to examine more critically the role they may play in water-flooding.

Static Conditions

Three active tension forces must be dealt with in the reservoir. These are interfacial tensions between oil and water (S_{ow}), solid and water (S_{sw}), and solid and oil (S_{so}). When these forces are in equilibrium:

$$S_{so} - S_{sw} = S_{ow} \cos\theta \qquad (1)$$

where θ, is the contact angle between two liquids, measured through the water phase. Expressed in terms of the opposing force, adhesive tension, A, the above relation becomes:

$$A_{sw} - A_{so} = S_{ow} \cos\theta \qquad (2)$$

When the right-hand side of the above equation is positive ($\theta < 90°$), water will displace oil from the solid; but when it is negative ($\theta > 90°$), oil will tend to displace water. Thus the contact angle becomes an important measure of the displacement phenomenon. In fact, since there is no convenient means of measuring solid-liquid interfacial tensions, measurement of the contact angle is the only direct way of determining the extent of and the direction in which displacement will take place. Unfortunately, in measuring contact angles, an hysteresis effect occurs which complicates interpretation of the measurements. It has been found that the water-advancing angle, formed when the water-oil interface is caused to move over a surface originally in contact with oil, is generally different from the water-receding angle formed when the interface moves over a surface originally in contact with water.[125] In many cases the advancing angle is greater than 90° whereas the receding angle is invariably less than 90°. The explanation of this occurrence may lie in the fact that polar impurities in the oil make the mineral surface hydrophobic. This is a very important observation for it indicates that displacement will depend upon whether the mineral grain surfaces were originally wet with oil or with water.

When an interface exists between an oil-saturated zone and a water-saturated zone in a sand-packed tube, the interface will tend to move in the direction of the non-wetting liquid. The pressure required to prevent the movement of the interface is known as the "displacement pressure." This is a measure of the wettability of the sand; the greater the pressure, the more readily the sand will be wet by the wetting liquid, and the more readily the second liquid will be displaced. Displacement pressure is more formally defined as "the static pressure that can be developed by the meniscus in the largest available interstice" [126] in the sand. Displacement pressure is related to the contact angle by the equation [127]

---

[125] Benner, F. C., Dodd, C. G., and Bartell, F. E., op. cit.

[126] Hassler, G. L., Brunner, E., and Deahl, T. J., The role of capillarity in oil production: Am. Inst. Min. Eng., Trans., vol. 155, pp. 155-174, 1944.

$$P_D = \frac{2S_{ow}\cos\theta}{rg} \tag{3}$$

where: "r" is a mean effective pore radius of the sand determined originally for the sand with liquids of known interfacial tension and contact angle. Although this relation has been verified by experiments, it has been pointed out that the mean effective radius may be dependent upon the contact angle of the particular fluid-solid system used in calibration.[128]

Since the contact angle of any fluid-solid system is independent of the grain size of the solid,[129] the above relation indicates that the finer the sand, the greater is the displacement pressure for the particular system. This has been repeatedly verified by laboratory experimentation and strengthens the statement that displacement phenomena are more pronounced in fine-grained sands than in coarse-grained sands.

Displacement pressure is analogous to capillary pressure at 100 percent saturation, or the minimum capillary pressure.[130] To gain a better knowledge of the latter term, it will be well to review the work of Garrison,[131] Leverett [132] and others.[133] The interfacial boundary between two fluids coexisting in a pore space is a curved surface, the sharpness of the curvature depending upon the size of the pore and the proportions of the fluids present.[134] This curvature is a result of the interfacial tension between the fluids which in turn is an attribute of the free surface energy tending toward a minimum. The curvature gives rise to a pressure differential across the interface which has been termed the "capillary pressure". At equilibrium, the two are related by the expression:[135]

$$P_c = S_{ow}\left[\frac{1}{R_1} + \frac{1}{R_2}\right] \tag{4}$$

where, because of the nature of intergrain contacts, there are two principal radii of curvature of the interface, R_1 and R_2. By considering the change in free energy involved in transferring a small volume of water in a system in capillary equilibrium an upward distance (dh), Leverett derives the relation between capillary pressure and height above the level of zero oil saturation as:

$$P_c = \Delta\rho_{av}gh = S_{ow}\left[\frac{1}{R_1} + \frac{1}{R_2}\right] \tag{5}$$

where: $\Delta\rho_{av}$ = average difference in densities between oil and water
g = gravitational constant
h = height above the level of zero oil saturation.

---

[127] Benner, F. C., Dodd, C. G., and Bartell, F. E., op. cit.
[128] Hassler, G. L., Brunner, E., and Deahl, T. J., op. cit.
[129] Benner, F. C., Dodd, C. G., and Bartell, F. E., op. cit.
[130] Hassler, G. L., Brunner, E., and Deahl, T. J., op. cit.
[131] Garrison, A. D., op. cit.
[132] Leverett, M. C., Capillary behavior in porous sands: Am. Inst. Min. Eng. Trans., vol. 142, pp. 152-169, 1941.
[133] Benner, F. C., Riches, W. W., and Bartell, F. E., op. cit.
Hassler, G. L., Brunner, E., and Deahl, T. J., op. cit.
[134] Leverett, M. C., op. cit.
[135] Leverett, M. C., op. cit.

As mentioned earlier, capillary pressure is also a function of the proportions of the fluids present. Capillary pressure measurements indicate that water saturation decreases with increase in capillary pressure from 100 percent saturation at displacement pressure, to an irreducible minimum value at some higher pressure. No two curves are alike, because of the complex geometry of the pore spaces of each sand; so that, although the curve for any one system may be reproducible, its shape is determined by the pore pattern. Leverett[136] states that there is a theoretical possibility of determining the mean curvature mathematically for a given water saturation in an interstice of given dimensions, but that the complexity of pore sizes and shapes in reservoir sands makes such a possibility very remote.

Even though it may not be possible to relate interfacial curvature and pore size analytically, it is possible to deduce the distribution of pore sizes from saturation-capillary pressure curves. For example, a high displacement pressure indicates small pore sizes, whereas low displacement pressures mean large pore sizes. A large rate of decrease in water saturation with increase in pressure indicates uniform pore sizes, whereas the converse would indicate a wide distribution of pore sizes. Again, a low irreducible water content probably indicates a low clay content and a minimum of dead-end pores. The above analysis presupposes fluid-solid systems in which the contact angles are the same.

Dynamic Aspects

The foregoing discussion applies for the most part to static systems in capillary equilibrium. The problem of capillary and surface forces under dynamic conditions is much more complex. The two forces available for the removal of oil from the reservoir which concern water-flooding are the imposed pressure gradient and surface forces. It has generally been considered that flooding should proceed at such a rate as to balance these two forces and to attain a uniform water-oil interface with a minimum of bypassing. If water is injected at too rapid a rate, surface forces will not be effective in stripping the sand grains of all of their oil and in recovering oil from the finer interstices. Bypassing of oil in tight streaks is known to be common and Garrison[137] attributes this to the differential permeability of the sand. He also points out that if the rate of water injection were slow enough to permit capillary equilibrium to be approached, an exact reversal of recovery effectiveness from sands of different texture would occur. There is no quantitative way of deriving a balance between the two forces. At the present time the rate of advance is controlled by economic considerations.

Leverett[138] has introduced the effect of capillarity into the general equations governing the flow of fluids in porous media to make them more applicable to actual reservoir conditions. Including in Darcy's law not only pressure and gravity gradient but also a capillary gradient, the three forces which cause motion of the fluids will have been accounted for. This will give the resultant expression for f_w, the fraction of the flowing stream composed of water. By setting appropriate boundary conditions, the following relation should give reasonable results.

---

[136] Op. cit. (1941).
[137] Op. cit.
[138] Op. cit. (1941).

$$f_w = \frac{1 + \frac{K_o}{q_t \mu_o}\left[\frac{\delta P_c}{\delta u} - g\Delta\rho \sin \propto\right]}{1 + \frac{K_o}{K_w}\,\frac{\mu_w}{\mu_o}} \qquad (6)$$

where: q_t = total rate of flow
$\propto$ = angle made by the direction "u" with the horizontal, and other terms as described previously.

One further aspect of capillarity which should be mentioned is the vertical migration of fluids. In a virgin reservoir all forces are considered to be in equilibrium. However, when the reservoir has been opened to production, equilibrium no longer exists and fluids migrate in an attempt to re-establish this state of equilibrium. In cases where there are two or more beds of different permeabilities and with different capillary pressure-saturation relations, in direct contact with one another, capillarity will be effective in causing vertical migration and redistribution of fluids.[139] Capillarity may cause either upward or downward migration, depending upon the circumstances, as a result of unequal depletion of beds.

Importance to Water-Flooding

In summarizing the influence of surface and capillary forces in water-flooding, it can be seen that their effects enter in many and devious ways. In systems composed of pure water, most pure hydrocarbons, and most common mineral grains, water has a decided tendency to displace oil. The addition to the water of any substance which will decrease the solid-water and oil-water interfacial tensions, will increase the effectiveness of displacement by water. On the other hand, many crude oils contain polar compounds which may become adsorbed at mineral-grain surfaces, rendering the surfaces hydrophobic. This makes the recovery of oil from grain surfaces and finer capillary interstices virtually impossible. The direction and magnitude of displacement may be deduced from contact-angle and displacement-pressure data.

The concept of capillary pressure is likewise of importance in water-flooding, for by means of the so-called "restored state method" it is possible to deduce equilibrium water saturation and irreducible water content. This is of decided aid in estimating reserves and predicting flow characteristics. Capillary pressure gradient has also been included in Darcy's law in an attempt to calculate accurately the flow of fluids through porous media.

There are still other applications of these forces to production technology but their significance in water-flooding is somewhat obscure.

Principles of Fluid Displacement

The various properties of the reservoir and its contained fluids, and the forces active in the reservoir have been discussed and this information must now be applied to the phenomena which occur in the sands when water is injected into them under pressure.

---

[139] Hassler, G. L., Brunner, E., and Deahl, T. J., op. cit.

Displacement from Sand Bodies

Buckley and Leverett[140] have given an excellent account of the dynamics of displacement by water. Water, as it leaves the injection well under the imposed pressure gradient, enters a region of high oil saturation causing displacement of the oil therefrom and changing the region to one in which the water saturation is high. The displacing water apparently does not behave as a piston forcing water out of the pores but, rather, oil and water flow through the pores simultaneously; therefore displacement can never be complete. If the region to be invaded has a high oil saturation, it likewise has a high relative permeability to oil and a correspondingly low permeability to water. Displacement should be very effective at this stage because of the lack of mobility of the water through the zone of high oil saturation. As water invades the region, however, the permeability relations become reversed and residual oil has little tendency to flow because of the high water saturation. These have been termed the ''initial'' and ''subordinate'' phases of displacement, respectively.

The interface between the oil and water during the initial phase might be considered as a plane if only saturation-relative permeability relations were considered. This is not the case, however, for capillarity and gravity have a modifying influence resulting in a transition zone, its width depending primarily upon the rate of displacement.[141]

The viscosity ratio $\frac{\mu_o}{\mu_w}$ has a marked influence on the efficiency of the initial phase of displacement. In neglecting the effects due to gravity and capillary pressure the relation given by Leverett for the fraction of water in the flowing stream reduces to:

$$f_w = \frac{1}{1 + \frac{K_o \ \mu_w}{K_w \ \mu_o}}$$

From this relation it can be seen that the higher the viscosity ratio, the greater will be the amount of water flowing and the greater will be the amount of oil left behind. This results in a low water saturation during the initial phase and a gradual approach to minimum oil saturation during the subordinate phase.[142]

Actually the important effect of viscosity is the stability of the interface. Because a less viscous fluid is displacing a fluid with a relatively high viscosity, the boundary between the two is unstable and the greater the viscosity difference the greater is the instability. Extensive bypassing by the water will occur in reservoirs containing high viscosity oil.[143]

The effect of the initial fluid saturation on the two phases of displacement may be deduced from earlier discussion. The existence and duration of the initial phase will depend upon the saturations, for, if the connate water saturation should exceed that which would be attained during the initial phase, this phase will be absent. In this case no water-free oil production could be expected, but rather, the small amounts of oil and large amounts of water common to the subordinate phase.

---

[140] Op. cit.
[141] Buckley, S. E., and Leverett, M. C., op. cit.
[142] Buckley, S. E., and Leverett, M. C., op. cit.
[143] Van Wingen and Johnston, op. cit.

Combining the effects of viscosity and saturation, Van Wingen [144] states that if the mobility of water is greater than the mobility of the oil, water-flooding may not be economically feasible because of excessive water-oil ratios. Mobility is defined here as the ratio of the effective permeability of the sand to a fluid-phase, to reservoir viscosity of the fluid.

Buckley and Leverett [145] discuss further the influence of capillary and gravitational effects in displacement. In the reservoir capillary and gravitational forces oppose each other, the former tending to prevent saturation discontinuities in a homogeneous sand and the latter tending to promote vertical segregation of fluids according to their densities. At very low displacement rates, saturation is probably controlled by the balance between these two forces. At high displacement rates, frictional forces are probably sufficiently great to obscure the effects of both, and flow is determined primarily by fluid viscosities and relative permeabilities.

In a heterogeneous formation, the effect of capillarity becomes very pronounced. When such a formation is in equilibrium, water is distributed throughout the sands in different concentrations and to different heights, depending on the fineness of the sands, so as to satisfy capillary equilibrium. As the level of zero capillary pressure is changed by encroaching edgewater or by water injection, the water saturation changes throughout the reservoir in order to re-establish equilibrium. If the water level is made to rise slowly enough, capillary equilibrium will be approached and water will tend to rise higher in the fine sands, expelling the oil therefrom, while the main body of water will follow, displacing oil from the coarse sands. If, however, the rate of rise of the water level is too rapid, the water will not have an opportunity to even approach equilibrium in the finer sands and the oil will remain trapped in them as they are passed by the main body of water. This explanation accounts for a good deal of the oil left unrecovered in heterogeneous formations.

Displacement from Individual Pores

Ryder [146] discusses the principles of fluid displacement by consideration of the fluid distribution in individual pores. Although the actual distribution of fluids in pores is not known, he has prepared a series of diagrams showing several possible distributions as deduced from laboratory and field observations. The first of the two diagrams of interest to this discussion shows a pore pattern as copied from a micro-photograph of a thin section, in which the pore surfaces are water-wet and the oil saturation is between 30 and 35 percent. When a moderate pressure gradient is applied, the water moves through the sand but there is no oil movement. The water moves around the oil droplets that occur in the center of the pores, and on through the flow channels. The only effect of the oil droplets is to plug the flow channels and restrict the water flow. This action is thought to be an attribute of the high oil-water interfacial tension. It appears to be similar to the Jamin action where insufficient force is available to cause the distortion of the oil droplets sufficiently to permit their movement through the finer constrictions.

The second diagram shows conditions similar to the first except that the pore surfaces are hydrophobic and are covered with a thin film of oil.

---

[144] Van Wingen and Johnston, op. cit.

[145] Op. cit.

[146] Ryder, H. M., Effect on production of fluid distribution and relative permeability in sand: World Oil, June 1948, pp. 142-150.

When a high pressure gradient is imposed, water moves through the pores; but in this case, because of the film of oil on the grains, it must move through the oil and push oil forward to make space for the following water. The purpose of the high pressure gradient is to make the water stream cross-sectional area as large as possible to assure pushing the oil ahead of it and, in addition, stripping some of the oil from the pore surfaces. Were a low pressure—low velocity flood employed in this case, there would be insufficient energy available to overcome the adsorption forces holding the oil to the pore walls. An additional effect of low pressure would be to cause trapping of oil in the smaller interstices because the force is insufficient to cause water to enter and remove the oil.

In conclusion, Ryder states that in the case of water-wet sands with low oil saturation, water-flooding would not be successful. Even if the oil saturation were high, he concludes that gas-drive would be more successful than water-drive. Oil-wet sands with low water saturation should be water-flooded at high pressures and high velocities for maximum recovery. Oil-wet sands with both high water and high oil saturations could probably only be produced by means of a gas-drive to remove excess water followed by a high pressure water-drive.

Summary

The above principles have been verified indirectly by field and laboratory evidence. The two phases of displacement may be observed in the laboratory and to a lesser degree deduced by examination of field production records. There is no direct way of learning the nature of the distribution of fluids in individual pores but the principles discussed by Ryder have been substantiated by field observations. Too little is known regarding the distribution of fluids in reservoir rock pore spaces and the mechanics of displacement therefrom. This is a problem of some magnitude in water-flooding and should be thoroughly investigated in any contemplated research program.

Principles of Fluid Flow

The foregoing discussion has been more concerned with the mechanics of fluid displacement than with the principles of fluid flow through extensive media. It is this latter condition with which we are ultimately concerned, for it is important to be able to predict the rates and ease with which large quantities of fluids can be caused to move through the reservoir.

Mathematical Analysis

Mathematical analyses of flow can be made in a variety of ways but they are all based on the fundamental law of Darcy. In its most fundamental form, this law may be expressed as:

$$Q = -\frac{k\ A}{\mu}\ \text{grad}\ \phi \qquad (1)$$

where: Q = volume rate of flow
k = permeability of the medium
A = cross-sectional flow area
μ = viscosity of fluid flowing
grad ϕ = potential gradient causing flow, including pressure, capillary force, and gravity.

Considering the radial case of a single-phase fluid flowing horizontally into a well, Muskat[147] gives the following expression of Darcy's law:

$$Q = \frac{2\pi kh(p_e - p_w)}{\mu \ln \frac{r_e}{r_w}} \tag{2}$$

where: h = sand thickness
p_e = reservoir pressure
p_w = pressure at well
r_e = drainage radius
r_w = well radius

and other terms are as previously described. This relation is readily derived from equation (1). Under the conditions specified, grad ϕ becomes equal to $\frac{dp}{dr}$ and "A" becomes equal to $2\pi rh$. Substituting these values into equation (1):

$$Q = -\frac{k2\pi rh}{\mu}\frac{dp}{dr} \tag{3}$$

Integrating equation (3) between the limits r_w, p_w, and r_e, p_e, yields equation (2) as given by Muskat.

This relation holds either for flow from an injection well or flow into a producing well when a single-phase fluid is flowing. In the case of a water injection well, the only fluid flowing from the well is water so that this requirement is satisfied. The value of "r_e" is somewhat difficult to determine precisely but since it enters the equation as a logarithm, errors as high as 50 percent in estimating its value will result in but few percent error in calculation of flow rates. Dickey and Andresen[148] state that in the case of an injection well, the value of "r_e", the average distance to which the pressure has extended outward from the well, can be calculated from the porosity of the sand, its fluid content, and the cumulative volume of water injected.

In the case of a production well, the above relation cannot be used in the form given, for generally three phases, (oil, gas, water) are flowing simultaneously. If water and oil only are flowing, the following relation may be employed:

$$Q = \frac{2\pi h(p_w - p_e)}{\left[\frac{\mu_w}{k_w} + \frac{\mu_o}{k_o}\right] \ln \frac{r_e}{r_w}} \tag{4}$$

where all terms have been defined earlier. The three-fluid case becomes extremely complex because of the compressibility of the gas phase. A third relation of the same general type as equation (4), given by Leverett and including gravity and capillary potential, has already been discussed.

Although such mathematical analyses are often useful in estimating flow in the reservoir, the difficulties of evaluating the several variables, the lack of uniformity of reservoir conditions, and the complexity of boundary conditions, make rigorous analytical treatment very complex. Such expressions given in integrated form assume highly idealized conditions: concentric boundaries, uniform pressure distribution, and uniform permeability within the boundaries. Other difficulties arise in the common case of multiphase flow. For example, relative permeability is a function of saturation and saturation varies considerably in the reservoir, especially when gas is present.

---

[147] Muskat, Morris, The flow of homogeneous fluids through porous media, New York, McGraw-Hill Book Co., Inc., 1937.

[148] Dickey, P. A., and Andresen, K. H., The behavior of water-input wells: Am. Petroleum Inst. Drilling and Production Practice, pp. 34-58, 1945.

The first set of variables has been treated analytically by Muskat [149] for the single-phase case. He has given the solution to problems involving non-concentric boundaries, unequal pressure distributions, and anisotropic media in which the nature of the variations are known. Muskat has further analyzed the multi-well situations commonly encountered in oil fields and has developed expressions for "flooding efficiencies" and "conductivities" for several well-spacing patterns from consideration of the geometry of the patterns.

Although this work represents a creditable advance in the knowledge of flow conditions, the major problems remain unsolved. O'Brien and Putnam [150] have applied the work of Wyckoff and Botset and others to multi-phase flow problems with some success. Again, idealized conditions of uniform boundaries and pressure distributions, uniform permeability, and horizontal flow were employed. In general, mathematical analyses alone are not satisfactory for the calculation of reservoir flow problems.

Model Studies

Many engineering problems which contain so many variables as to be unsolvable by analytical means, can be solved by the use of dimensional analysis and dimensionally scaled models. For example, in the case of unsteady flow of a two-component mixture through porous media, the equation of continuity in the following form may be employed:[151]

$$\frac{\delta}{\delta x} q_{tx}\, f_x + \frac{\delta}{\delta y} q_{ty}\, f_y + \frac{\delta}{\delta z} q_{tz}\, f_z = - P \frac{\delta S}{\delta \theta} \qquad (5)$$

where: q_t = total rate of flow and subscripts x, y, and z refer to the three coordinate directions.
f = fraction of the flowing stream comprising water.
P = fractional porosity
$\frac{\delta S}{\delta \theta}$ = rate of change of saturation with time.

The expression for "f_u" given previously as:

$$f_u = \frac{1 + \frac{K_o}{q_{tu}\,\mu_o}\left(\frac{\delta P_c}{\delta u} - g\ \Delta\rho \cos\alpha\right)}{1 + \frac{K_o}{K_w}\,\frac{\mu_w}{\mu_o}} \qquad (6)$$

could be differentiated with respect to the three coordinate directions and the results inserted into equation (5). The resultant expression would completely define the flow, but its mathematical solution would be impossible. However, if all the physical variables can be evaluated and a dimensionally scaled model constructed, solution of the problem does become possible.

---

[149] Op. cit. (1937).

[150] O'Brien, M. P., and Putnam, J. A., Some problems of horizontal steady flow in porous media: Am. Inst. Min. Eng. Petroleum Tech., July 1941.

[151] Leverett, M. C., Lewis, W. B., and True, M. E., Dimensional-model studies of oil field behavior: Am. Inst. Min. Eng. Trans., vol. 146, pp. 175-193, 1942.

Leverett, Lewis, and True [152] constructed such a model in which all the physical properties were scaled to the prototype, by considering the two fundamental laws of dimensional analysis. These laws state that "two systems are dimensionally similar or dimensionally scaled if for each element in one system there is a corresponding element in the second system and the ratios of the numerical magnitudes of corresponding elements are constant for all elements of the same dimensional type," and that "only as many dimensionally independent properties as there are fundamental dimensions may be fixed."

It was found possible to determine the amount of water produced with the oil under various conditions of flow rate, well completion, and oil-zone thickness. It was further possible to determine oil recovery as a function of the many variables influencing the amount of oil recovered by water displacement. There are certain limitations to the method, however, which restrict its usefulness. For example, a length ratio of 16 required a permeability ratio of $\frac{1}{64}$ so that permeability of the model was necessarily high. To obtain a high permeability, a relatively well-sorted, coarse sand was required and it is known that relative permeability-saturation relations break down for very coarse sands. This imposes a limit to the length scale and thus a limit to the areal extent which can be represented in a model. Another limitation is the fact that no hydratable material may be present in the model so that such a model must be considered as representing only a portion of an idealized reservoir.

Electrical Models. Electrical models have proven useful in predicting the flow of fluids in a reservoir. With the aid of such models it is possible to determine the arrangement of input and recovery wells to give maximum flooding efficiency. It is also possible with the use of electric models and a scaling method to predict pressure conditions and advance of the water-flood at any time in the life of the project, if bypassing is assumed to be negligible.

All electrical models are based on the same principle, which is the analogy existing between the flow of electric current through a conducting medium and the flow of fluids through a porous medium. Thus the analogy is between Ohm's law and Darcy's law respectively. Ohm's law may be expressed as:[153]

$$I = -\frac{1}{r}\frac{\delta E}{\delta x} \qquad (7)$$

where: I = current flowing
r = specific resistivity
$\frac{\delta E}{\delta x}$ = voltage gradient

Darcy's law is expressed as:

$$u = -\frac{k}{r}\frac{\delta P}{\delta x} \qquad (8)$$

---

[152] Leverett, M. C., Lewis, W. B., and True, M. E., Dimensional-model studies of oil field behavior: Am. Inst. Min. Eng. Trans., vol. 146, pp. 175-193, 1942.

[153] This analysis is similar to that given in Horner, W. L., and Bruce, W. A., Electrical model studies of secondary recovery: Am. Petroleum Inst. Prod. Bull. 230, pp. 190-198, 1943.

These two laws become identical when:

$$\frac{1}{r} = \frac{k}{\mu} \qquad (9)$$

In this case, electrical potential is equivalent to pressure, and current to fluid flow. These equations could not be used directly for compressible fluids because of the incompressibility of electricity. However, in the application to water-flooding, the incompressible case can be assumed to apply and the above equations used directly.

Integration of equations (7) and (8) for the case of radial flow will give respectively:

$$p_1 - p_2 = \frac{q_u \mu}{2\pi k h_F} \ln \frac{r_e}{r_w} \qquad (10)$$

$$E_1 - E_2 = \frac{i r}{2\pi h_E} \text{ in } \frac{r_e}{r_w} \qquad (11)$$

where "h_F" and "h_E" are the thicknesses of the formation and the electrical conducting medium, respectively. Since the distance scale is linear, the value of the ratio $\frac{r_e}{r_w}$ can be made to correspond in model and prototype.

It can be seen from equations (10) and (11) that the electrical resistance in ohms, R_E, would be:

$$R_E = \frac{r}{h_E} \qquad (12)$$

and the fluid resistance, R_F:

$$R_F = \frac{\mu}{k\ h_F} \qquad (13)$$

The scale ratio between these two values is then given by:

$$n = \frac{R_E}{R_F} = \frac{\frac{r}{h_E}}{\frac{\mu}{k\ h_F}} \qquad (14)$$

The ratio between the electrical potential difference, in volts, and the pressure difference, in lbs/in² is then:

$$m = \frac{p_1 - p_2}{E_1 - E_2} \qquad (15)$$

The current-fluid flow ratio must then be fixed by the above two ratios so that:

$$q = m\ n\ i \qquad (16)$$

With the above relations, an electrical model can be constructed so that flow properties can be expressed in terms of electrical units and a reservoir analyzed under various conditions of flow. From this analysis, the selection of injection and producing wells in an old field or the spacing pattern in a new field may be made, to give maximum flooding efficiency Also important in this connection are the rates of injection and production of individual wells which will give maximum efficiency. The distance of travel of the flooding front at any time and the time for depletion of the reservoir at any given injection and production rates may also be studied.

Electrical models have not been used as extensively as they might be in the case of water-flooding.[154] There are, as in all such work, certain limitations which detract from their usefulness. For example, it is difficult to take into consideration the variations in permeability which exist in all reservoirs. Hurst [155] has shown how the problem of vertical variation in permeability can be handled in electrical model studies. Where each permeable section can be traced over a structure and considered a unit in a parallel arrangement of sand layers, the principle of "parallel flow" can be applied. It is assumed that the potential distribution is the same in each layer but that because of the greater resistance in the lower permeability layers, the rate of flow is reduced. The rate of flow in each sand is proportional to the product of permeability and sand thickness.

Lateral variations in permeability, however, cannot be accounted for unless the variation is uniform. Variation in sand thickness can be corrected by change in model thickness. On the other hand, such factors as multi-phase flow and relative permeability, difference in viscosity of driving and driven fluids, non-horizontal formations, and others cannot readily be accounted for in the electrical model. Nevertheless, electrical-model studies should prove very useful in predicting and controlling fluid flow in water-flooding.

Summary

The foregoing discussion can be summarized in but a few brief statements. Mathematical analyses of fluid flow are of primary importance in predicting the flow characteristics of production or injection wells. These relations become too complex to be of appreciable value when dealing with multi-well—complex boundary situations. In this latter case, the electrical model has become of importance. Although there are limitations in the use of electrical models, valuable information as to well-spacing, flooding efficiency, and the advance of the water-oil interface may be obtained. Even though at the present time these models will play an important role in the planning of water-flooding projects, additional research should be undertaken to eliminate some of the existing limitations.

Injection Rates and Pressures

Two of the very few controllable factors in water-flooding are injection pressures and the resultant injection rates. Unfortunately, more confusion seems to exist as to the proper range of these two values than any of the other factors, controllable or uncontrollable. In the final analysis it appears that the most effective injection pressure and rate vary with the particular field and the reservoir conditions encountered. The following is a summary of the field and laboratory evidence supporting the various points of view.

Injection Pressures

It is difficult to discuss injection pressures without mentioning volumetric injection rates, for it can be seen from Darcy's law that the one is directly dependent upon the other. However, there are certain effects and limiting conditions which may be discussed independently.

---

[154] Horner, W. L., and Bruce, W. A., op. cit.

[155] Hurst, W., Electrical models as an aid in visualizing flow in condensate reservoirs: Petroleum Eng. Midyear 1941, p. 123.

It is obvious that a lower limit to injection pressures is imposed by reservoir conditions. This pressure must be sufficient to cause the flow of fluids towards recovery wells by overcoming reservoir pressure and the resistance to flow offered by viscous, frictional, and inertial forces. Thus, the minimum injection pressure is a function of reservoir depth, permeability of the sands, viscosity of the fluids, and other factors. Minimum pressure, however, is of minor significance to the operator for he is more interested in the pressures required for the various rates of injection.

Of more importance is the maximum pressure the reservoir can withstand without inflicting damage to the wells or to the surrounding formations. Various authorities [156] have placed this maximum value as between 1.5 and 2 lbs/in^2 per foot of depth minus the equivalent of hydrostatic head. The maximum value varies with reservoir conditions but it must be low enough to prevent lifting the overburden, which results in the migration of injection fluids along shale breaks or other bedding planes. In consideration of the pressure distribution in a reservoir under the influence of injection through input wells, it would appear that the greatest damage due to excessive pressures would be in the close vicinity of the injection well. Examination of pressure distribution curves about a producing well will disclose that the greatest pressure drop is adjacent to the well-bore itself.[157] This is characteristic of radial flow and is an attribute of increased fluid velocity with decreased flow area as the well-bore is approached. The same situation would prevail in the case of an injection well, the high injection pressure being dissipated rapidly close to the well-bore.

It is difficult to accept the above maximum limits for injection pressures without considerable qualification. This limit is expressed as a function of depth alone whereas the reservoir pressure which must be overcome by injection pressure is certainly not a function of depth alone. Reservoir pressure is dependent upon the pressure exerted by the edgewater and the nature and extent of the overburden and its contained fluids. Maximum injection pressure is also a function of these factors but the amount it may be made to exceed reservoir pressure is almost wholly conditioned by the nature of the reservoir and its overburden. If excessive pressures are employed in reservoirs which have potential zones of weakness, the disastrous results of channeling may occur. Thus higher maximum injection pressures may be employed in fields and zones where shale or other breaks are negligible and confining beds are thick and impermeable, than in fields where these ideal conditions are not present. Lawry [158] cites several examples of channeling through streaks of coal and lignite and carbonaceous shales. However, he states that in no instance has it been known that clean sand parted from excessive pressure.

It is apparent that by these and perhaps other considerations it is possible to determine the upper and lower limits of injection pressure. The problem now remains to determine whether the pressure to be used in practice shall be closer to the upper or the lower limit. This problem becomes closely associated with volume rates of injection. Earlougher[159] in a series of "flood pot" tests on consolidated core samples, found that the oil recovery was influenced by pressure only in that the imposed pressure determined the rate of flow. He concluded that the rate of flow governed the efficiency of oil recovery regardless of the pressure required. On the other hand, Cable[160] states that there is both field and laboratory evidence to indicate that the higher the pressure to which the reservoir is subjected, the greater is the ultimate recovery of oil. He considers this as due, in part, to the variation in threshold pressure with bore diameter.

---

[156] Van Wingen and Johnston, op. cit.
Cable, J. H., Preliminary field tests for determining required injection volumes and pressures: Am. Petroleum Inst. Prod. Bull. 230, pp. 147-150, 1943.

[157] Muskat, M., The flow of homogeneous fluids through porous media, New York, McGraw-Hill Book Co., Inc., p. 154, 1937.

[158] Lawry, T. F., Flowing water flood production: Am. Petroleum Inst. Prod. Bull. 232, pp. 45-50, 1946.

Other laboratory data contradict Earlougher's conclusions. Henderson and Yuster[161] found that the effective permeability to oil is a function of pressure. In doubling the imposed pressure on a core with 30 percent oil and 70 percent water saturation, the effective permeability to oil was tripled. Ryder,[162] a firm advocate of high pressures and high injection rates in water-flooding, explains this phenomenon to be a result of the fluid distribution within the sand pores. Although this is probably an exceptional case, it is reasonable to assume that pressure does have an influence on fluid distribution with a corresponding influence on effective permeability. This leads to the possibility that in certain cases, higher injection pressures may increase oil recovery.

The use of high pressures might also be advantageous from an entirely different standpoint. If sufficient pressure can be applied to injection wells without damage to the formations, the benefits of free flow might be realized. Lawry[163] has deduced that pressures sufficient to promote flowing water-flood production will recover the same ultimate amount of oil as lower pressures and yet will reduce initial costs and operating expenses.

Injection Rates

The rate at which water can be injected into reservoir sands has a strong bearing on the financial success of a flooding project. The well and reservoir should be capable of taking water at the most efficient rate and permitting that rate to be maintained throughout the life of the project. The present discussion is not concerned with the intake characteristics of wells, but rather, with the most efficient rate of injection. For purposes of the following discussion it will be assumed that the well and field as a whole are capable of taking water at any desired rate.

The most efficient rate of injection may be defined as that rate which will recover the greatest amount of oil with the least amount of water, within a reasonable length of time. It has been stated earlier that this rate possibly should be such as to give a balance between surface displacement forces and hydraulic pressure. This view is held by many authorities[164] who advocate low rates of injection. F. G. Miller and H. C.

---

[159] Earlougher, R. C., Relationships between velocity, oil saturation and flooding efficiency: Am. Inst. Min. Eng. Trans., vol. 151, p. 125, 1943.

[160] Op. cit. (1943).

[161] Henderson, J. H., and Yuster, S. T., Studies in relative permeability: World Oil, March 1948, pp. 139-147.

[162] Ryder, H. M., Effect on production of fluid distribution and relative permeability in sand: World Oil, June 1948, pp. 142-150.

[163] Op. cit.

[164] Earlougher, R. C., Relationships between velocity, oil saturation, and flooding efficiency: Am. Inst. Min. Eng. Trans., vol. 151, p. 125, 1943.

Parsons, R. L., The recovery efficiency of a water drive as a function of the rate of advance of the oil-water interface, unpublished thesis, University of California, 1940.

Uren, Lester C., Increasing oil recovery by flooding: National Petroleum News, August 3, 1927, p. 54.

Miller [165] in reviewing the literature in the not dissimilar problem of edgewater encroachment, point out that in many fields having active edgewater drives, oil is removed at a higher rate than it can be replaced by the encroaching water. Were the rate of oil production reduced to the point where water immediately filled the voids, the greatest use of the natural force of water-drive would be realized. With excessive rates of oil production, however, water will seek the zones of highest permeability, resulting in fingering and bypassing of oil in the tighter sands. The actual rate of advance in water-drive fields is highly variable but the above review indicates that it is of the magnitude of 0.4 to as high as 2.74 feet per day. On the other hand, water-flooding rates are much lower, 0.033 to 0.22 foot per day. This would indicate that perhaps the higher recovery efficiency in water-flooding as compared to natural water-drive, is a result of the lower flooding rate.

The magnitude of surface forces in effecting the removal of residual oil films is not known. However, slow rates of water advance tend to maintain a uniform water-oil interface and prevent bypassing of oil in the tighter sands. This is possibly of greater importance in field practice than is the displacement of oil from individual grain surfaces. In laboratory experimentation where idealized porous media are used, surface forces may predominate, making lower flooding rates more efficient.

The work of Earlougher [166] showed that there is a critical maximum flooding velocity for any given oil saturation which, if exceeded, results in a rapid drop in flooding efficiency. Although he found that ultimately about the same total amount of oil could be produced at the higher velocities, the water-oil ratio increased so rapidly as to make the flood uneconomical early in its life. It was further noted that the critical maximum velocity varied directly with oil saturation. Through both laboratory work and the examination of production records, it was concluded that for sands with low oil saturation (30 percent), the injection rate should be about one barrel per foot of sand per day, but that it can be increased to 5 barrels per foot of sand per day for oil saturations as high as 45 to 50 percent.

Considerable other evidence is available to substantiate the increased recovery efficiency attained with lower flooding rates. The laboratory work of Uren,[167] Rankin,[168], and Parsons [169] has all indicated improved efficiencies at lower rates. Although these tests were made under idealized conditions, there are also field data to verify the findings.

There are certain objections to low injection rates which are worthy of consideration. Foremost among these is the limitation imposed by economic considerations. Obviously, oil must be produced at or above a certain minimum rate to make the flooding project economically feasible. Thus, it may be necessary to employ an injection rate higher than that deemed most efficient. This is the situation that arises whenever the margin of profit is narrow and it becomes necessary to violate pure scientific principles to insure the economic success of the undertaking. The best that can be done in such a case is to determine the minimum rate of production necessary to support the project economically and to fix the required injection rate accordingly. Considerably more information from laboratory tests and reservoir data may be required for borderline cases.

---

[165] Miller, F. G., and Miller, H. C., Resume of problems relating to edgewater encroachment in oil sands: U. S. Bur. Mines Rept. Inv. 3392, March 1938.

[166] Earlougher, R. C., Relationships between velocity, oil saturation, and flooding efficiency: Am. Inst. Min. Eng. Trans., vol. 151, p. 125, 1943.

[167] Uren, L. C., Increasing oil recovery by flooding: National Petroleum News, August 3, 1927, p. 54.

[168] Rankin, D. R., A laboratory investigation of the effect of rate on the recovery of oil by water-flooding; paper presented before Am. Inst. Min. Eng. Petroleum Div. meeting at Los Angeles, October 19, 1939.

[169] Parsons, R. L., op. cit.

In studying the encroachment of edgewater, a laboratory investigation by Miller,[170] in which sand-packed tubes were employed, disclosed that oil recovery was increased at increased rates of water encroachment. Flooding velocities employed were within the range of 0.058 to 7.23 feet per day. The results showed further that the influence of the rate of encroachment on oil recovery was more pronounced at lower than at higher rates. Miller tentatively concluded that surface forces were ineffective in recovering oil under the conditions of the tests. Objections might be voiced to investigations employing vertical tubes and upward displacement of oil by water. It is possible that the floating action due to the difference in densities of displacing and displaced fluids, might mask other effects. Another objection to the results of Miller, pointed out by Van Wingen,[171] is that connate-water content was not adequately accounted for in the tests.

Ryder [172] is one of the strongest advocates of high injection rates and correspondingly high pressures. His analysis and conclusions are based primarily on the nature of the fluid distribution within the pores. Accordingly, he has deduced that water-wet sands are not suited to water-flooding regardless of the oil saturation. On the other hand, oil-wet sands should be water-flooded at high pressures and high injection rates. High pressures are presumably effective in preventing the trapping of oil in the smaller interstices, which would probably result if low pressures were employed. The advantage of high injection velocities is to furnish energy to overcome the forces of adsorption and reduce the thickness of the oil film adhering to the grain surface.

Dickey and Buckwalter [173] have also defended the case of higher injection rates and have presented several arguments in its favor. There is field evidence to show greater recovery at higher rates in adjacent properties, although this may have been the result of other factors. It is possible, however, that higher rates will recover, from less permeable sand zones, oil which would not have been recovered at lower rates in a reasonable length of time. These authors conclude that although there is probably some optimum flooding velocity for each sand, the conflicting evidence obtained from laboratory and field observations make this value impossible to estimate.

If the assumption is made that ultimate recovery is independent of the rate of flooding, there are many obvious factors in favor of higher rates. These include more rapid recovery of oil with resultant rapid pay-off on investment, the use of wider well-spacing, and the possibilities of flowing production, and consequent reduced operating expenses.

---

[170] Miller, F. G., A laboratory study of water encroachments in oil-filled sand columns: U. S. Bur. Mines Rept. Inv. 3595, 1941.

[171] Van Wingen, N., and Johnston, N., Current concepts of secondary recovery: Am. Petroleum Inst. Drilling and Production Practice, 1946, pp. 196-208.

[172] Ryder, H. M., Effect on production of fluid distribution and relative permeability in sand: World Oil, June 1948, pp. 142-150.

[173] Dickey, P. A., and Buckwalter, J. F., Advantages of increased injection rates at water-input wells: Am. Petroleum Inst. Drilling and Production Practice, 1946, pp. 230-235.

Summary

Evidence as to the proper injection pressures and rates to attain maximum recovery is conflicting and it appears that no set formula can be applied in all cases. Each reservoir must be studied independently and an injection program developed with the proper balance between scientific principles and economics.

Minimum and maximum permissible injection pressures may be determined as previously indicated. The volume rate of injection for any pressure within this range may be estimated by means of the radial flow formula if permeability and other factors can be properly evaluated. Laboratory experimentation and pilot injection tests would be of great help in verifying the theoretical calculations.

The most advantageous pressure and volume rate within the above range is difficult to determine. Economics will have a strong bearing in this determination, for obviously the recovery rate must be sufficient to pay the expenses of the project. To the present time it appears that rates have been determined largely by past experience. Since there is a minimum of field experience to fall back on in California, and since reservoir conditions are considerably different from other areas, a more scientific basis must be employed.

A few general principles can be stated which might serve as a guide in determining the most beneficial rates. In the case of highly variable sand texture and permeability, such as are common to California, lower rates of injection should be employed. This should minimize the bypassing of oil in tight sands by permitting the approach to capillary equilibrium. At these low rates, surface forces, if of sufficient magnitude, should be effective in increasing the displacement of oil and the overall recovery efficiency. Higher injection rates may be safely employed in uniform sands, and possibly in non-uniform sands when oil viscosities are low.

Whenever possible, the reservoir should be maintained at a high pressure level by restricting the production rates until high fluid levels are attained in producing wells. This is a common practice in primary production, for it conserves and maintains reservoir energy at a high level. High pressures are also effective in forcing free gas into solution, thus decreasing oil viscosity and increasing effective liquid permeability.

Where reservoir sands are definitely known to be oil-wet, the application of high pressure gradients and high injection rates appears practical. The stripping action should add considerably to the total oil production. The operator should proceed with caution, however, for channeling may offset this advantage.

More research work will be necessary to give an answer to this perplexing problem. Even then it may be necessary to proceed on a trial and error basis to build up a sufficient backlog of field experience upon which future work may be based.

Well Spacing, Completion and Behavior

Consideration must now be given to the matter of the wells to be employed in the flooding project. A well pattern should be selected which will give the maximum flooding efficiency. The wells should be spaced at such a distance as to make the application of excessive injection pressures unnecessary and yet to maintain development costs as low as possible. New wells must be completed and old wells reconditioned so as to give the most efficient injection and production characteristics. The behavior of input wells and their ability to take water at a constant rate should be fully understood. These and many other similar factors are important in determining the success or failure of a flooding project.

Flooding Patterns

Several different arrangements of injection and production wells may be employed. In developing a spacing pattern, consideration must be given to the proportion of the reservoir area which can be swept out by the injection water. Flooding efficiency, the ratio of the area swept out to the total area concerned, defines this property.

Muskat[174] has developed, mathematically, the flooding efficiencies of several common well patterns. The direct line drive, consisting of alternate lines of production and injection wells uniformly spaced, has a flooding efficiency of only 57 percent. The staggered line drive in which the alternate lines of either producing or injection wells are offset half the distance between wells, may have an efficiency as high as 80 percent, depending upon the ratio of the distance between wells in the two directions. The five-spot pattern is a special case of the staggered line drive in which a producing well is in the center of a square made up of four injection wells, one at each corner of the square. Flooding efficiency of the five-spot is 73.2 percent. The seven-spot pattern consisting of a producing well at the center of a hexagon with injection wells at each corner, has a flooding efficiency of 74 percent. In a nine-spot pattern, the efficiency is increased to 78.1 percent.[175]

It should be remembered that these efficiencies are for wholly idealized conditions and it is doubtful whether they would be attained in actual practice. Lateral variations in permeability would distort the shape of the area swept out by the flood. The usual result would be to decrease the area flooded and, correspondingly, the flooding efficiency. Vertical permeability variation also affects the flooding efficiency. Since more permeable beds will be flooded out before the less permeable ones, the theoretical efficiency will not be attained because either the produced water-oil ratio will become uneconomically high or, even more disastrous, the more permeable beds may serve as escape channels for the injection water, bypassing oil in tight beds. Nevertheless, the above mathematical analysis is of value in that it indicates the relative efficiencies of the several patterns.

There are other spacing patterns which should be considered. In steeply dipping structures it may not be practical to employ the intensive blanket-flooding discussed above. It may be found desirable in this case to locate injection wells down the dip of the structure at or near the oil-water contact, thus permitting injection water to augment the forces of natural encroachment. As the water advances up dip and enters the first row of producing wells, these wells then become the new injection wells. This method can be highly efficient, especially if the wells are arranged in the form of a staggered line drive. This is somewhat similar to the first type of pattern ever employed in water-flooding, known as the circle flood. In this case a center well was used for injection, and production was from encircling wells. This latter method is usually rejected in favor of intensive flooding whenever possible.

---

[174] Op. cit. (1937).

[175] Muskat, M., The theory of nine-spot flooding networks: Prod. Monthly, March 1948, pp. 14-17.

In reviewing the many water-flooding projects in operation throughout the country, it was found that the five-spot pattern was by far the most common. In many cases, however, the patterns were modified to permit the use of old wells or to take into account lease boundaries. Muskat [176] summarizes the influence of flooding pattern by stating that, as all patterns give close to the same efficiency, the selection of a pattern should be made principally on the basis of economic considerations.

Well Spacing

Closely related to flooding patterns is the problem of well spacing, which in turn is mostly a matter of economics. A higher rate of recovery can be obtained by closer well spacing, yet the cost of additional wells required for close spacing will probably reduce the ultimate profit. Undoubtedly the question is the profit and payout time desired on the original investment.

There is little evidence one way or the other to indicate the influence of well spacing on ultimate oil recovery. In consideration of the energy dissipation in the reservoir, wide spacing would appear to be more efficient. It has been shown that the greatest dissipation of energy (or pressure) is in the close vicinity of the well-bore. Thus, at least in primary production, a disproportionate amount of energy is consumed in the areas close to the wells. The total effect in close spacing of wells is the consumption of more energy per barrel of oil produced than would be the case in wider spacing. This would likewise apply to the artificial energy supplied in water-flooding.

In water-flooding, there is no apparent direct relation between energy consumption and ultimate recovery. From the standpoint of economics, however, there is a very important relation between these factors for the greater the energy required to recover a barrel of oil, the greater is the cost of the oil per barrel. This will have the effect of reducing the economic life of the project and, correspondingly, the ultimate recovery of oil.

The effect of well spacing on recovery rates can be deduced directly from Darcy's law. Muskat [177] shows that in the case of a line drive or five-spot pattern, doubling the spacing for a given applied pressure will reduce the oil production rate by only 11 percent. This, as explained earlier, is a consequence of the drainage radius (corresponding to the distance between recovery and injection wells in this case) entering the radial flow formula as a logarithm.

Regardless of the above considerations most authorities indicate that wider spacing results in a lower recovery of oil.[178] There are two possible explanations for this belief, aside from field experience. The most important is the fact that closer spacing offers the advantage of better control of injection and production. Operators are better able to maintain a uniform advance of the flood water if more wells are available for its control. This is particularly true in fields displaying a considerable lack of lateral uniformity in sand characteristics, for the chances of accounting for regional variation in permeability and clay content are much better when wells are closely spaced.

---

[176] Muskat, M., Theoretical considerations involved in secondary recovery operations: Am. Petroleum Inst., Secondary Recovery of Oil in U. S., chapt. 4, pp. 31-36, 1942.

[177] Op. cit. (1942).

[178] Fancher, G. H., The development and operation of secondary water-flooding projects: Am. Petroleum Inst. Secondary Recovery in the U. S., chapt. 6, pp. 48-60, 1942.

A second factor is the higher pressure required to maintain the same production rate in the case of widely spaced wells. The disadvantages of high injection pressures mentioned earlier include the danger of lifting the overburden, the development of fractures and zones of weakness resulting in loss of fluids, and the increased danger of channeling and bypassing of oil in tight sands.

Well spacing is a function of both sand characteristics and economics, and a satisfactory balance between these two must be attained. Maximum spacing limit may be determined from permeability of the sands, desired production rate, and the maximum pressure that can be employed without damage to the well or the formations. Obviously, the lower the permeability of the sands, the closer the spacing must be to obtain economic recovery rates at reasonable pressures. The lower limit of well spacing is controlled exclusively by economic considerations. The closer the well spacing, the greater are the development costs which must be offset by increased production rates.

In past water-flooding practice, spacing between like wells has ranged from 215 to 660 feet.[179] This indicates a spacing of from about 1 to 10 acres per one producing well and one injection well, considerably closer spacing than normally practiced in primary fields. Fancher [180] has stated that spacing distance has increased in the Bradford area until, at the present time, it takes about 6 years, on the average, for the depletion of a five-spot pattern.

Yuster [181] has very carefully analyzed the problem of well-spacing in water-flooding, purely on a theoretical basis as far as the reservoir is concerned, but considering all economic factors. He has derived empirical equations, based on experience in the Bradford area, from which development and operating costs and gross income from the project can be estimated. By equating the sum of the first two to the third, the ''break-even'' spacing can be determined. ''Break-even'' spacing is here defined as the well spacing at which no profit and no loss will be realized. In comparing break-even spacing under flowing and pumping production it was found that in Bradford the minimum spacing was 144 and 178 feet respectively, while in the Mid-Continent the spacing was 240 and 430 feet respectively. The wider spacing in the Mid-Continent area was a reflection of the lower selling price obtainable for the crude oil.

By means of the equations developed by Yuster, other limiting conditions such as depth, price of oil, and oil saturation can be deduced. Further application of these equations in combination with Darcy's law permits the evaluation of the effects of rate of production and flood-out times. It is indicated that in the Bradford area, well spacing and production rates are planned so as to complete the flooding program in about 10 years, or at the most 15 years. Yuster states that 10 years is the most desirable in that equipment repairs and other maintenance costs will be at a minimum during this period. This is an important experience factor which should also be considered in well spacing.

---

[179] Fancher, G. H., op. cit.
[180] Op. cit.
[181] Yuster, S. T., Water-flood spacing: Oil and Gas Jour., December 20, 1947, p. 71.

The Use of Old Wells

Heath [182] has discussed the possibilities of the use of old wells for water-flooding and some of his more important conclusions will be mentioned here. He concludes that, in general, old wells can be satisfactorily adapted for use in secondary recovery and that in so doing, substantial savings can be made in development costs. The use of old wells will increase the feasibility of secondary recovery in deeper fields and therefore extend its application. In discussing the above paper, Earlougher states that although it is considered preferable to have new wells to use for injection, it has been found that old wells are usually as efficient for both production and injection.

Most of the older fields, especially in California, have been over-drilled from the standpoint of efficient primary recovery. There should be sufficient wells available for almost any desired flooding pattern and well spacing. The mechanical condition of these old wells will be questionable and the flooding pattern will have to be based on the wells that can be reconditioned at a reasonable cost. The erratic spacing pattern of these old fields may dictate the need for additional wells to be drilled. The number of new wells that can be drilled is a matter of economics and depends upon the depth of the reservoir and drilling and completion costs. It appears that here the use of the electrical model would be an aid in selecting the wells to be used for the project, in indicating which should be injection and which production wells, and in determining the location of new wells.

Muskat [183] and Heath [184] have stated that well spacing and spacing patterns are not as critical as economic considerations namely, development and reconditioning costs. Thus, the operator need not be too concerned if the spacing pattern offered by existing reconditionable wells does not follow one of the accepted forms. The resultant well spacing may be greater than that dictated by past experience, yet the savings in development costs will go a long way in paying off the increased cost of higher-pressure injection or in balancing the lower production rates.

One difficulty in the use of existing wells in old fields is the usual lack of core-analysis and electrical-log data. Such information is essential in planning reconversion work. The operator must know the location of water sands, barren sands, thief sands, and tight and loose oil sands, so that he can intelligently complete or recondition the well. If a rather thorough knowledge of these conditions is not available, it is imperative that a minimum number of new wells be drilled in order to obtain the necessary data. These wells should be drilled at such locations as to give a complete picture of underground conditions, and yet with the thought in mind that they will be completed and become a part of the flooding pattern.

There are many other difficulties encountered in the use of old wells which must be attended to in the reconversion process. One of the most serious is the presence of badly corroded and leaking casings. It is rarely possible to remove the water-string, repair and reinstall it, without caving the hole. If the badly corroded sections and points of water entry are located, cement jobs might be effective. Each well is an individual study in this respect. If an analysis of the damage indicates high repair costs, the well should not be considered for water-flooding.

---

[182] Heath, W. A., The utilization of old wells: Am. Petroleum Inst. Prod. Bull. 232, pp. 18-23, 1946.

[183] Op. cit. (1942).

[184] Op. cit. (1946).

The deposition of paraffin or asphaltic residues and the precipitation of salts on the wall of the well are common difficulties in old wells. These do not present too difficult a problem, for the use of cleanout tools, heat, solvents, acids, or shooting is generally effective.

Water intrusion into the productive formation about the well bore creating a "water logged" condition is a problem with which it is more difficult to contend. If the amount of water is small, Heath [185] suggests the injection of oil or gas to dissipate the water. If this fails, or if a larger amount of water is present, the well can only be used as a water-injection well. This may cause but a minor readjustment of the flooding pattern.

These and many other problems will be encountered in utilizing old wells for water-flooding. These problems are certainly not insurmountable and the savings will help to assure the success of water-flooding projects.

Delayed Drilling

In planning the development program for water-flooding, perhaps some consideration should be given to the principle of delayed drilling. It has been advocated that if the input wells are drilled first and water injection commenced before the production wells are drilled, a more uniform flooding front will be obtained. The water penetrates the more highly permeable sands first, but, as there is no outlet, the penetration ceases a certain distance from the input wells. This permits the water to enter the tighter sands and eventually penetrate to a point where a uniform bank of oil is built up surrounding the location of the producing well. The oil well is drilled from 6 to 18 months later and peak production is encountered at once.[186]

This method may result in a more complete recovery from heterogeneous sands by reducing the amount of bypassing. Phillippi [187] states, however, that no benefits could be expected from delayed drilling in uniform sands. A possible disadvantage of the method is the loss in production time. Since most projects do not attain peak production rates until the second year,[188] this objection is possibly invalid.

Well Completion and Reconditioning

Little need be said regarding the completion of new wells and reconditioning of old wells for water-flooding. The methods and practices are essentially the same as those employed in primary completions. It is important that core records and electrical logs are obtained and carefully analyzed to determine the method of completion. Barren thief sands and water sands must be effectively packed or sealed off. It may be necessary to acidize or shoot tight sands in both producing and injection wells. Consideration might be given to gravel packing new or even reconditioned wells to increase injection and production capacities.

---

[185] Op. cit. (1946).

[186] Phillippi, P. M., Analysis of delayed drilling program in water-flooding: Petroleum Eng., April 1940, p. 103.

[187] Op. cit.

[188] Fancher, G. H., The development and operation of secondary water-flooding projects: Am. Petroleum Inst. Secondary Recovery in the U. S., chapt. 6, pp. 48-60, 1942.

Injection wells require some additional attention. It is of course desirable to maintain a uniform advance of the flood water in all beds in the reservoir. This can be accomplished to a certain degree by packing off and selectively injecting water in accordance with the permeability of each zone. Another method which has met with varying degrees of success is known as selective plugging. If some substance can be injected into the well which will deposit in the larger pores of the more permeable sands, reducing their permeabilities and yet not affecting the permeability of tighter sands, much more efficient oil recovery may be expected. Several substances have been employed, such as Portland cement, talc, and zinc oxide, but they were only superficially effective in that they deposited primarily as a filter cake on the face of the sands and were very unstable. The use of colloidal dispersions of wax have been much more successful, for they are known to actually penetrate the sands. However, Kennedy [189] reports that the results are still not lasting and that dispersions prepared from rosin-type solids in water are far superior. Martin [190] describes a commercial product known as Dresinol which is still more effective. This agent is a resin in water emulsion, which is apparently quite stable and effectively reduces permeability for a considerable length of time. Still other substances have been described in the literature, such as the various types of smokes.[191]

Behavior of Injection Wells

For successful water-flooding, injection wells must be capable of taking large quantities of water at sustained rates. If these conditions are not present at the outset, or if they become unsatisfactory later in the life of the project, appropriate remedial measures must be taken.

Dickey and Andresen [192] have thoroughly discussed the behavior of water-input wells. When water is first injected into the well, the reservoir takes water at a maximum rate. As the partially depleted pore spaces become filled with liquid, the injection rate progressively decreases. After a period of time the rate declines more slowly until, when the reservoir liquid saturation becomes essentially 100 percent, the rate becomes constant and remains so over long periods of time. One might expect the rate of injection to increase somewhat after the minimum has been reached, for as oil is removed from the reservoir by the flood water, the effective permeability to water should increase. This is seldom, if ever, the case; the rate usually continues to decline slightly as injection proceeds.

The decline in injectivity of wells is a problem common to many water-flooding projects. This decrease in the ability of wells to take water is often caused by plugging of the interstices of the formation about the well-bore. Suspended solids, chemical precipitates, and organic substances in the injection water may all be effective in plugging the interstices and reducing the rate of water intake. Remedial measures include acidizing and shooting and subsequent improvement of the quality of injection water to minimize further plugging.

---

[189] Kennedy, H. T., The use of plugging agents: Am. Petroleum Inst. Prod. Bull. 232, pp. 51-53, 1946.

[190] Martin, D., Andresen, K. H., and Ellenberger, F. W., Recent advances in selective exclusion of water in input wells: Oil and Gas Jour., April 19, 1947, p. 106.

[191] Nielson, R. F., Report on selective plugging with smoke: Prod. Monthly, December 1947, pp. 15-18.

[192] Op. cit.

A second cause of decline in the injectivity of wells is the swelling of clays in the formation promoted by injection water. This condition is usually impossible to remedy and adequate precautions should be taken at the outset to minimize swelling. A knowledge of the types and amounts of clay present in the formation will dictate the most appropriate pH value and salt content of the injection water.

It is desirable to estimate the amounts of water which can be injected into a well at given pressures, before the project is commenced. Injection volume rates can be calculated mathematically with the use of Darcy's law for the radial case. This relation has been given earlier as:

$$Q = \frac{2\pi kh(p_e - p_w)}{\mu \ln \frac{r_e}{r_w}} \qquad (1)$$

The value of "r_e", the outward limit of the water bank, is continually increasing as injection proceeds. It can be expressed most conveniently in terms of the total volume of water injected, or the volume of water necessary to completely saturate the formation out to "r_e". This relation is given by:[193]

$$V = \pi h r_e^2 f(1 - S_r - w) \qquad (2)$$

where: f = fractional porosity
S_r = fractional residual oil saturation after the flood waters have passed
w = fractional interstitial water saturation.

Differentiating equation (2) with respect to time gives:

$$\frac{dV}{dt} = Q = 2\pi h r_e f(1 - S_r - w)\frac{dr_e}{dt} \qquad (3)$$

Equating this expression to the value of Q in equation (1) and separating variables:

$$r_e dr_e(\ln r_e - \ln r_w \qquad \frac{k(p_e - p_w)dt}{\mu f(1 - S_r - w)} \qquad (4)$$

Integrating between the limits "r_w" and "r_e", and simplifying:

$$r_e^2(\ln \frac{r_e^2}{r_w^2} - 1) + r_w^2 = \frac{4k(p_e - p_w)t}{\mu f(1 - S_r - w)} \qquad (5)$$

Solving equation (1) for "r_e", substituting this value into equation (5), and simplifying:

$$\frac{4k(p_e - p_w)t}{\mu r_w^2 f(1 - S_r - w)} = 1 + \left[\frac{4\pi kh(p_e - p_w)}{\mu Q} - 1\right] e^{\frac{4\pi kh(p_e - p_w)}{\mu Q}} \qquad (6)$$

This final relation makes it possible to calculate rate of water injection as a function of time. A series of calculations will yield data from which a very useful graph of injection rates versus time may be plotted.

In the case of several injection wells this relation will hold only up to the time when the encroaching liquid bank meets banks from neighboring wells. At this point interference takes place and the intake rate is reduced until the steady conductivity of the flow pattern is reached. For the five-spot spacing pattern, this steady rate is given by:[194]

---

[193] Yuster, S. T., and Calhoun, J. C., Water injection wells and their behavior: Oil Weekly, December 18, 1944, p. 28.

$$Q = \frac{\pi k h \Delta p}{\mu \ln \frac{D}{r_w} - 0.619)} \qquad (7)$$

where: Δp = difference in sand face pressure between input and producing wells

D = distance between input and producing wells.

Although these mathematical analyses will give an estimate of the injectivity of an individual well or group of wells, it is desirable to test each well early in the life of the flood to check these calculations. Injection tests are run at several pressures and the "injectivity index" of the well determined. The "injectivity index" is defined [195] as "the number of barrels per day of gross liquid injected into a well per pound per square inch pressure differential between mean injection pressure and mean formation pressure referred to a specific sursurface datum, usually the mean formation depth." This value is useful in checking analytical calculations. Such work as a whole is of value in determining plant capacities, recovery rates, and in detecting plugging of the sand face about the well bore.

Economics of Water-Flooding

No discussion of water-flooding would be complete without an analysis of the economics involved. Obviously, an operator must be assured of a reasonable chance of success before undertaking extensive development of such a project. Fortunately, it is easier to predict the success or failure of water-flooding than is the case with a wildcat drilling program. Here, through years of primary production experience, considerable knowledge is available concerning reservoir characteristics and production behavior that would not be known in a new and unproved area. With this information at hand, and with more tangible cost data available from past experience, the success of the project can be predicted. If conditions are favorable, a flooding plan may be developed from which the greatest ultimate profit will be realized.

Costs as Compared to Primary Production

Analysis of the economics of water-flooding can best be made by comparison to primary recovery. The economics of the two types of production are closely related. For example, the success of water-flooding is dependent to a large extent upon the selling price of oil and the price of oil is determined to an important degree by the cost of primary production.

The ever-increasing cost of finding new primary oil production is a factor favorable to secondary recovery methods in general. It is becoming more difficult to find each new field; exploratory methods are becoming more complex and more expensive; each new field means one less field to be found in the future. It has been estimated that the cost per new barrel of oil found has increased in the 10-year period, 1936-46, from 5.6 cents to 50.5 cents per barrel.[196] The situation has certainly not improved since that time, indicating that the average cost of finding new oil is perhaps close to 60 cents per barrel at the present time. In contrast, the cost of exploring for oil recoverable by secondary recovery methods is negligible. The presence of oil, in this case, is a proven fact, and the main problem is to determine whether oil can be recovered economically. This means that up to 60 cents per barrel can be applied to the greater development and production costs of secondary recovery.

---

[194] Dickey, P. A., and Andresen, K. H., op. cit.

[195] American Petroleum Institute, Glossary relating to a reservoir behavior, Report of the California Dist. Topical Comm. on Production Technology, November 8, 1943.

[196] Berwald, W. E., Economics of secondary oil recovery: Oil and Gas Jour., November 15, 1947, p. 317.

Primary development costs are increasing at a greater rate than can be attributed to the general increases in material and labor costs alone. This is a result of the ever-increasing drilling depths necessary to obtain new oil. Although the increased costs of deeper drilling have been offset somewhat by wider well-spacing, improved drilling equipment and methods, and unit operations, Berwald [197] estimates that primary development costs have doubled in the last 10-year period. Most secondary recovery projects have been limited to fields of shallow depths. Continually increasing primary development costs will tend to increase the depths at which secondary recovery will be economically feasible.

There are other factors in development costs which are of importance. The secondary recovery operator is able to plan a complete development program for he knows reservoir conditions and field limits. In many cases it is only necessary to drill a few additional wells to meet production and injection needs. All wells can be drilled or reconditioned in a short period of time, which practice will result in an additional saving. This is certainly not the case in a new or unproved field, for neither reservoir conditions nor productive limits are known. The operator must proceed with caution in determining the productive limits of the field and even then chances are that some non-productive or non-profitable wells will be drilled. It is difficult to foretell the total number of wells that will be required and to estimate total development costs early in the exploration program. This is entirely possible, however, in secondary recovery operations.

An additional point of significance in the comparison of development costs is the fact that well spacing is usually somewhat more dense in secondary recovery than in primary recovery. In many cases, however, especially where old wells can be used in the flooding project, this may be offset by the closer well spacing common to most of the older fields where water-flooding would be considered.

Production costs in secondary recovery, in contrast to exploration and development costs, are greater than in primary production. In primary production there is generally an abundance of natural reservoir energy available for the expulsion and production of the oil which, if properly utilized, will maintain costs at a very low level. Secondary recovery requires the injection of fluid into the reservoir to promote expulsion. This involves the added expense of a reliable supply of injection media and a special system for handling, treating, and injecting the fluid. Since secondary production rates are in most cases lower than primary rates, the production cost per barrel of produced oil is greater. The reverse is true, however, when comparing secondary production with stripper production, and this may become a strong point in favor of secondary recovery. In addition there are certain savings which may be realized in secondary production. Often much of the same equipment employed in primary production can be utilized. As well-head and pumping equipment, gathering, and storage facilities used in primary production will have generally been written off the books, use of this equipment in the secondary recovery project will reduce the capital expenditure. Often other used equipment is available which may be employed at a considerable saving.

---

[197] Op. cit.

Other benefits include the fact that the production capacity of a secondary project can be estimated with reasonable accuracy and will enter to an important degree in planning the production program, market outlets, etc., and in determining the rate of return on the investment. This eliminates a good deal of the uncertainty and risk involved in the development of new producing areas.

Physical Factors

The most important of the physical factors influencing the economics of water-flooding is the total amount of recoverable oil. Methods of deriving this value have already been discussed. Briefly, the total oil saturation in a low pressure—low permeability field can be determined from core analysis data. The residual oil content after flooding can be determined in the laboratory from flood-pot tests. The difference between these two values times the porosity will give the percent of oil per volume of reservoir sand that can be recovered by water-flooding. If flushing of cores is known to occur, more elaborate determinations will be necessary. In cases where it is not expedient to obtain cores or where a check is desired on core analysis data, a volumetric analysis will yield an approximation. This analysis can be made from an examination of past production records and a knowledge of reservoir temperatures and pressures. To this there must be applied a recovery factor to account for residual oil saturation. Still a third very approximate method is to assume that as much oil will be recovered by water-flooding as was recovered during the primary production period. Some engineers employ a safety factor and assume only 50 to 75 percent of the primary production will be recoverable by water-flooding. This derived or estimated value multiplied by the predicted price to be obtained for the oil will give the gross income from the project.

It is not safe to set a lower limit of recoverable oil below which water-flooding will not be successful, for there are too many factors to be considered. The lower limit depends strictly on the balance between gross income and costs for each individual case.

Other physical factors (namely sand permeability, oil viscosity, well spacing, and injection pressure and rate) will determine the rate at which oil may be recovered. Obviously, the production rate must be such as to pay off operating expenses and amortization of capital investment, and to yield a profit to the operator. The latter three physical factors listed above are controllable in that they can be adjusted, within limits, to give the desired rate of production. If it is desirable to obtain a higher production rate and a higher annual profit, closer well-spacing and higher injection rates and pressures must be employed. This will reduce the life of the project and may result in a somewhat lower ultimate recovery. In addition, the benefits of high recovery rates must be balanced against the increased development costs of closer well spacing. The production rate to be employed above that which will show a minimum profit depends largely on current and predicted future economic conditions. This includes such matters as selling price, supply, and demand for oil.

The depth of the reservoir has a pronounced influence on development and production costs and thus influences the economics of water-flooding. Few, if any, additional wells can be drilled in a deep field because of their prohibitive cost. Unless there are sufficient existing wells in satisfactory condition to serve for injection and production purposes, the development costs for a water-flooding project would become excessively high, and only when other conditions were unusually favorable would such a project be economically feasible. In addition, the cost of reconditioning wells for water-flooding increases rapidly with depth.

An advantage of greater depths which, however, does not offset the disadvantages, lies in the fact that greater pressures may be utilized without danger of lifting the overburden or causing channeling through weak formations. Greater pressures permit wider well spacing with a proportionate decrease in development costs.

The final physical factor to be considered is the cost of procuring, treating, and injecting water. Most important is a reliable year-around supply of usable water. It has been stated that one of the most common reasons for failure of secondary recovery projects has been the failure of the supply of injection medium. The amount of water required depends upon the cumulative injection rates of all input wells. The rates at which injection wells will take water can be calculated by methods indicated earlier, or by pilot tests. The total amount of water required during the life of the project will depend upon the amount of oil recovered and the amount of gas originally in the formation, as well as the recovery efficiency. The value varies between 5 and 20 barrels of water per barrel of oil produced and averages about 10 barrels.[198]

The amount of money that can be expended for the supply, treatment, and injection of water will depend upon all other cost and profit factors. Perhaps a word of caution would be appropriate regarding the treatment of injection water. Since treatment costs generally represent but a very small fraction of the total operating costs, careful and adequate treatment should be employed because of the important effect it will have on the success of the project.

Price, Supply, and Demand

One of the most important factors influencing the success of water-flooding is the price obtainable for the oil produced. The current high prices being paid for crude oil make water-flooding appear more and more attractive. That this present price structure will be permanent is nearly assured by the current supply and demand situation. It is very doubtful that supplies will increase or the demand decrease sufficiently in the future to materially affect prices.

The increased price of crude oil has been occasioned not only by increased costs but also by increased demand and somewhat unstable future supply. It is not correct to say that there is a definite oil shortage at the present time. However, looking into the future, the reserve situation is not favorable. The addition of billions of barrels of oil recoverable by water-flooding to our proven reserves would do much to stabilize the petroleum industry and our economy as a whole.

---

[198] Cable, J. H., op. cit.

Other Factors

There are many other factors to be considered in an economic analysis of water-flooding. A complete determination of all cost factors, development and operating, must be carefully made. Most of such data can be obtained from company records of past experience. Barton and Prentice [199] have made a recent cost analysis of a project in the Bradford area. Although the numerical data would not apply in other areas, the relative magnitude of costs and the cost analysis procedure should be helpful. Fettke [200] has also presented considerable detailed information concerning development and operating costs of water-flooding in the Bradford field. Here again, however, each company and each field will dictate its own methods of cost analysis.

The analysis of Barton and Prentice [201] showed that an intensive flooding program on a moderate to large scale will have a better chance of success than a small-scale project because of certain set expenses which must be met. Thus in a new flooding project where the operator deems it advisable to develop the project on a limited basis, the maximum economic efficiency will probably not be attained.

Summary

It appears that the determination of the success or failure of a water-flooding project must largely be based on economic considerations. The general economic picture is undoubtedly at as favorable a level as it is likely to be. Oil companies are attempting to bolster their petroleum reserves with the most extensive and expensive exploratory program ever undertaken. There is little question that new oil reserves will be found, but the cost will be high.

The petroleum industry has always operated on a high risk level. This policy has paid well in the past, but there are indications that the high risk factor is becoming too great. This is suggested by the current willingness of certain companies to bear the expense of developing and producing proven foreign areas with a very small margin of return. If this represents a trend toward conservatism, secondary recovery will become more popular in the future for it is characteristically a low-risk, low-profit undertaking. Berwald [202] estimates the risk factor in water-flooding to be only about 20 percent. This means that if adequate engineering and cost data are available there should be no more than one failure out of every five projects.

California presents no unique problems in this respect. California crude oil is valued somewhat less than that produced in other areas. This should be more than offset, however, by the greater demand and lower reserves to production ratio presently existing. Importing oil from other areas to meet the rising demand will cause further price increases. These and many other factors indicate that the economic outlook for water-flooding in California is becoming increasingly favorable.

---

[199] Barton, J. K., and Prentice, R. G., Cost study of a water flood in the Bradford field: Prod. Monthly, February 1948, pp. 27-30.

[200] Fettke, C. R., Bradford oil field, Pennsylvania and New York: Pennsylvania Geol. Survey Bull. M21, 1938.

[201] Op. cit.

[202] Op. cit.

Bibliography

American Petroleum Institute, Glossary relating to reservoir behavior, A report of the California District Topical Comm. on Production Technology, November 8, 1943.

Andresen, K. H., and Heck, E. T., Effect of properties of flood water on rate of input and oil production: Am. Petroleum Inst. Drilling and Production Practice 1946, pp. 236-243.

Andrus, D. T., Secondary recovery research: Interstate Oil Compact Quart. Bull., vol. 5, no. 2, pp. 16-26, August 1946.

Archie, G. E., The electrical resistivity log as an aid in determining some reservoir characteristics: Am. Inst. Min. Eng. Trans., vol. 146, pp. 54-62, 1942.

Babson, E. C., Sherborne, J. E., and Jones, P. H., An experimental water flood in a California oil field: Am. Inst. Min. Eng. Trans., vol. 160, pp. 25-33, 1945.

Barton, J. K., and Prentice, R. G., Cost study of a water flood in the Bradford field: Producers Monthly, February 1948, pp. 27-30.

Bates, T. F., Gruver, R. M., and Yuster, S. T., Influence of clay content on water conductivity of oil sands: Oil Weekly, vol. 123, no. 8, p. 48, October 21, 1946.

Benner, F. C., and Bartell, F. E., The effect of polar impurities upon capillary and surface phenomena in petroleum production: Am. Petroleum Inst. Drilling and Production Practice 1941, pp. 341-348.

Benner, F. C., Dodd, C. G., and Bartell, F. E., Evaluation of effective displacement pressure for petroleum oil-water-silica systems: Am. Petroleum Inst. Drilling and Production Practice 1942, p. 169.

Benner, F. C., Riches, W. W., and Bartell, F. E., Nature and importance of surface forces in production of petroleum: Am. Petroleum Inst. Drilling and Production Practice 1938, pp. 442-448.

Berwald, W. E., Economics of secondary oil recovery: Oil and Gas Jour., November 15, 1947, p. 317.

Breston, J. N., and Barton K., Field test of corrosion inhibitor for low pH flood water: Producers Monthly, vol. 12, no. 1, pp. 13-17, November 1947.

Breston, R. L., and Johnson, W. E., Effect of pH on water intake rates of oil sands: Producers Monthly, vol. 9, no. 12, pp. 19-23, October 1945.

Bruce, W. A., and Welge, H. J., Restored-state method for determination of oil in place and connate water: Oil and Gas Jour., July 26, 1947, pp. 223-238.

Buckley, S. E., and Leverett, M. C., Mechanism of fluid displacement in sands: Am. Inst. Min. Eng. Trans., vol. 146, pp. 107-116, 1942.

Cable, J. H., Preliminary field tests for determining required injection volumes and pressures: Am. Petroleum Inst. Prod. Bull. 230, pp. 147-150, 1943.

Cardwell, W. T., and Parsons, R. L., Average permeabilities of heterogeneous oil sands: Am. Inst. Min. Eng. Trans., vol. 160, pp. 34-42, 1945.

Crawford, J. G., Waters of producing fields in the Rocky Mountain region: Am. Inst. Min. Eng. Petroleum Tech., May 1948.

Crooker, J. T., and Schnoor, F. H., Waste water injection in the Stevens zone, Greeley field: Am. Petroleum Inst. Paper No. 801-22E, 1946.

Dickey, P. A., Influence of fluid saturation on secondary recovery of oil: Am. Petroleum Inst., Prod. Bull. 230, pp. 158-164, 1943.

Dickey, P. A., and Andresen, K. H., The behavior of water-input wells: Am. Petroleum Inst. Drilling and Production Practice 1945, pp. 34-58.

Dickey, P. A., and Bossler, R. B., Role of connate water in secondary recovery of oil: Am. Inst. Min. Eng. Trans., vol. 155, pp. 175-183, 1944.

Dickey, P. A., and Buckwalter, J. F., Advantages of increased injection rates at water-input wells: Am. Petroleum Inst. Drilling and Production Practice 1946, pp. 230-235.

Earlougher, R. C., Core analysis problems in the mid-continent area: Am. Petroleum Inst. Prod. Bull. 230, pp. 323-326, 1943.

Earlougher, R. C., Relationships between velocity, oil saturation, and flooding efficiency: Am. Inst. Min. Eng. Trans., vol. 151, p. 125, 1943.

Fancher, G. H., The development and operation of secondary water-flooding projects: Am. Petroleum Inst. Secondary Recovery in the U. S., chapt. 6, pp. 48-60, 1942.

Fettke, C. R., Bradford oil field, Pennsylvania and New York: Pennsylvania Geol. Survey Bull. M21, 1938.

Fettke, C. R., Dickey, P. A., and Torrey, P. D., Geological factors influencing secondary recovery: Am. Petroleum Inst. Prod. Bull. 232, pp. 151-154, 1943.

Garrison, A. D., Selective wetting of reservoir rock and its relation to oil production; Am. Petroleum Inst. Drilling and Production Practice 1935, p. 130.

Getman, F. H., and Daniels, F., Outlines of theoretical chemistry, 6th ed., New York, John Wiley & Sons, 1940.

Gilbert, C. M., Cementation of some California Tertiary reservoir sands: Jour. Geology (in press).

Griffiths, J. C., Clay research and oil development problems: Inst. Petroleum Jour., vol. 32, no. 265, pp. 18-31, 1946.

Grim, R. E., Relation of clay mineralogy to origin and recovery of petroleum: Am. Assoc. Petroleum Geologists Bull., vol. 31, pp. 1491-1499, 1947.

Hassler, G. L., Brunner, E., and Deahl, T. J., The role of capillarity in oil production: Am. Inst. Min. Eng. Trans., vol. 155, pp. 155-174, 1944.

Heath, W. A., Influence of viscosity of crude oil on secondary recovery: Am. Petroleum Inst. Prod. Bull. 230, pp. 171-176, 1943.

Heath, W. A., The utilization of old wells: Am. Petroleum Inst. Prod. Bull. 232, pp. 18-23, 1946.

Henderson, J. H., and Yuster, S. T., Studies in relative permeability: World Oil, March 1948, pp. 139-147.

Higgins, R. V., Productivity of wells and inherent influence of gas-oil ratios and water saturation: U. S. Bur. Mines Rept. Inv. 3657, 1942.

Holbrook, G. W., and Ellenberger, A. R., Source and purification of water supply: Am. Petroleum Inst. Secondary Recovery in the U. S., Supplement 2, pp. 45-50, 1947.

Horner, W. L., and Bruce, W. A., Electrical model studies of secondary recovery: Am. Petroleum Inst. Prod. Bull. 230, pp. 190-198, 1943.

Hughes, R. V., and Pfister, R. J., Advantages of brines in secondary recovery of petroleum by water-flooding: Am. Inst. Min. Eng. Trans., vol. 170, pp. 187-201, 1947.

Hurst, W., Electrical models as an aid in visualizing flow in condensate reservoirs: Petroleum Eng., Midyear 1941, p. 123.

Johnston, N., Core analysis interpretation: Am. Petroleum Inst. Drilling and Production Practice 1941, pp. 180-199.

Johnston, N., and Beeson, C. M., Water permeability of reservoir sands: Am. Inst. Min. Eng. Trans., vol. 160, pp. 43-55, 1945.

Kennedy, H. T., The use of plugging agents: Am. Petroleum Inst. Prod. Bull. 232, pp. 51-53, 1946.

Klinkenberg, L. J., The permeability of porous media to liquids and gas: Am. Petroleum Inst. Drilling and Production Practice 1941, pp. 200-213.

Krynine, P. D., Mineralogy of water flooding: Producers Monthly, vol. 3, no. 2, p. 10, 1938.

Krynine, P. D., Petrology and genesis of the Third Bradford sand: Pennsylvania State Bull. 29, 1940.

Lawry, T. F., Flowing water flood production: Am. Petroleum Inst. Prod. Bull. 232, pp. 45-50, 1946.

Leverett, M. C., Flow of oil-water mixture through unconsolidated sands: Am. Inst. Min. Eng. Trans., vol. 132, pp. 149-169, 1939.

Leverett, M. C., Capillary behavior in porous sands: Am. Inst. Min. Eng. Trans., vol. 142, pp. 152-169, 1941.

Leverett, M. C., and Lewis, W. B., Steady flow of gas-oil-water mixtures through unconsolidated sands: Am. Inst. Min. Eng. Trans., vol. 142, pp. 107-116, 1941.

Leverett, M. C., Lewis, W. B., and True, M. E., Dimensional-model studies of oil field behavior: Am. Inst. Min. Eng. Trans., vol. 146, pp. 175-193, 1942.

Martin, D., Andresen, K. H., and Ellenberger, F. W., Recent advances in selective exclusion of water in input wells: Oil and Gas Jour., April 19, 1947, p. 106.

Miller, F. G., A laboratory study of water encroachments in oil-filled sand columns: U. S. Bur. Mines Rept. Inv. 3595, 1941.

Miller, F. G., and Miller, H. C., Resume of problems relating to edgewater encroachment in oil sands: U. S. Bur. Mines Rept. Inv. 3392, 1938.

Miller, L. E., Fundamental chemistry of the effects of hydrogen ions on water-intake rates of oil sands: Producers Monthly, vol. 11, no. 1, pp. 35-38, November 1946.

Mullane, J. J., Pressure core analysis: Am. Petroleum Inst. Drilling and Production Practice 1941, pp. 163-179.

Muskat Morris, The flow of homogeneous fluids through porous media, New York, McGraw-Hill Book Co., Inc., 1937.

Muskat, Morris, Theoretical considerations involved in secondary recovery operations: Am. Petroleum Inst. Secondary Recovery of Oil in U. S., chapt. 4, pp. 31-36, 1942.

Muskat, Morris, The theory of nine-spot flooding networks: Producers Monthly, March 1948, pp. 14-17.

Nielson, R. F., Report on selective plugging with smoke: Producers Monthly, December 1947, pp. 15-18.

O'Brien, M. P., and Putnam, J. A., Some problems of horizontal steady flow in porous media: Am. Inst. Min. Eng. Petroleum Tech., July 1941.

Parsons, R. L., The recovery efficiency of a water drive as a function of the rate of advance of the oil-water interface: Graduate thesis, University of California, 1940.

Phillippi, P. M., Analysis of delayed drilling program in water-flooding: Petroleum Eng., April 1940, p. 103.

Plummer, F. B., Merkt, E. E., Power, H. J., et al., Effect of micro-organisms on the injection of water into sand: Am. Inst. Min. Eng. Petroleum Tech., January 1944.

Plummer, F. B., and Walling, I. W., Laboratory investigations of chemical changes in east Texas oil-field water affecting its injection into subsurface sands: Am. Inst. Min. Eng. Trans., vol. 165, pp. 64-77, 1946.

Preckshot, G. W., et al., Asphaltic substances in crude oils: Am. Inst. Min. Eng. Trans., vol. 151, pp. 188-205, 1943.

Rankin, D. R., A laboratory investigation of the effect of rate on the recovery of oil by water-flooding, A paper presented before the Am. Inst. Min. Eng. Petroleum Div., October 19, 1939, at Los Angeles.

Reed, Ralph D., Position of California oil fields as related to geologic structure: California Div. Mines Bull. 118, p. 97, 1943.

Riggs, C. H., Water-flooding of the McClosky limestone: Producers Monthly, vol. 9, May 1945, pp. 12-18.

Ross, C. S., and Hendricks, S. B., Minerals of the montmorillonite group: U. S. Geol. Survey Prof. Paper 205B, 1945.

Russell, M. B., Soil moisture sorption curves for four Iowa soils: Soil Sci. Soc. America Proc., vol. 4, no. 51, 1939.

Russell, R. G., Morgan, F., and Muskat, M., Some experiments on the mobility of interstitial water: Am. Inst. Min. Eng. Trans., vol. 170, pp. 51-61, 1947.

Ryder, H. M., Character of pores in oil sands: World Oil, April 1948, pp. 129-134.

Ryder, H. M., Effect on production of fluid distribution and relative permeability in sand: World Oil, June 1948, pp. 142-150.

Schlumberger, C., and Leonardon, E., Electrical coring—a method of determining bottom-hole data by electrical measurements: Am. Inst. Min. Eng. Trans., vol. 110, pp. 237-289, 1934.

Somerton, W. H., Foaming tendency and stability of crude oil foams: Am. Petroleum Inst. Drilling and Production Practice, pp. 145-158, 1943.

Thornton, O. F., and Marshall, D. L., Estimating interstitial water by the capillary pressure method: Am. Inst. Min. Eng. Trans., vol. 170, pp. 69-80, 1947.

Tickell, F. G., Examination of fragmental rocks, Stanford University Press, 1931.

Torrey, P. D., The economics of secondary recovery operations: Am. Petroleum Inst. Secondary Recovery of Oil in the U. S., chapt. 2, pp. 16-25, 1942.

Tyrrell, G. W., The principles of petrology, New York, E. P. Dutton & Co., 1929.

Uren, L. C., Increasing oil recovery by flooding: National Petroleum News, August 3, 1927, p. 54.

Uren, L. C., Petroleum production engineering, vol. 2, Exploitation, New York, McGraw-Hill Book Co., Inc., 1939.

Uren, L. C., and Fahmy, E. H., Factors influencing the recovery of petroleum from unconsolidated sands by water-flooding: Am. Inst. Min. Eng. Trans., vol. 77, p. 318, 1927.

Van Wingen, N., and Johnston, N., Current concepts of secondary recovery: Am. Petroleum Inst., Drilling and Production Practice, 1946, pp. 196-208.

Waldschmidt, W. A., Cementing materials in sandstones and their probable influence on migration and accumulation of oil and gas: Am. Assoc. Petroleum Geologists Bull., vol. 25, p. 1839, 1941.

Wyckoff, R. D., and Botset, H. G., Flow of gas-liquid mixtures through unconsolidated sands: Physics, vol. 7, pp. 325-345, 1936.

Yuster, S. T., Water-flood spacing: Oil and Gas Jour., December 20, 1947, p. 71.

Yuster, S. T., and Calhoun, J. C., Water injection wells and their behavior: Oil Weekly, December 18, 1944, p. 28.

ZoBell, C. E., Functions of bacteria in the formation and accumulation of petroleum: Am. Petroleum Inst. Rept. of Progress on Fundamental Research, 1944-45, pp. 73-78.

NOTE: Part 2 of this paper, A SURVEY OF CALIFORNIA CONDITIONS RELATIVE TO THE APPLICATION OF WATER-FLOODING, will be published in the July, 1949, issue of the California Journal of Mines and Geology.

MINERAL RESOURCES OF KERN COUNTY *

By W. B. Tucker, R. J. Sampson, and G. B. Oakeshott

OUTLINE OF REPORT

Page
Abstract ---- 204
Introduction ---- 205
Topography ---- 205
Streams ---- 205
Transportation ---- 205
Mineral resources ---- 206
Metallic minerals ---- 206
Antimony ---- 206
Arsenic ---- 207
Copper ---- 208
Gold-silver ---- 209
Lead-zinc ---- 238
Tin ---- 238
Tungsten ---- 239
Nonmetallic minerals ---- 241
Borates ---- 241
Cement ---- 244
Clay ---- 245
Feldspar ---- 246
Gypsum ---- 247
Perlite ---- 249
Pumice ---- 249
Salt ---- 250
Volcanic ash and pumicite ---- 250
Tabulated list of mines in Kern County ---- 252
Metals ---- 252
Nonmetals ---- 276
Oil and gas ---- 280
Introduction ---- 280
Location of oil and gas fields ---- 280
Acknowledgment ---- 280
Kern County mineral production ---- 280
Reserves of oil and gas ---- 281
Recent general developments ---- 283
Geologic occurrence ---- 283
Development and production since 1940 ---- 283
East side fields ---- 283
West side fields ---- 288
Central Valley floor fields ---- 292
Southern fields ---- 295
Dry gas fields ---- 296

Illustrations

Fig. 1. Diagrammatic plan and section of the Baker mine ---- 242
Plate 9. Opal pumice deposits, El Paso Mountains ---- 220–221
10. H. M. Holloway, Inc. *A*, Mining gypsum; *B*, Hauling gypsum ---- 220–221
11. Monolith Portland Cement Company; *A*, Cement plant; *B*, Quarry ---- 220–221
12. *A*, Lost Hills oil field; *B*, Edison oil field ---- 220–221
13. *A*, Cudahy volcanic ash deposit, Last Chance Canyon; *B*, High Peak tungsten mill ---- 220–221
14. Golden Queen mine ---- 220–221
15. Long Beach Salt Company ---- 220–221
16. Pacific Coast Borax Company ---- 220–221
17. Map showing mines and mineral deposits of Kern County ---- In pocket
18. Oil fields of western Kern County ---- In pocket

---

* The section on *Oil and Gas* was prepared by Gordon B. Oakeshott, Associate Geologist, Geologic Branch, State Division of Mines; the remainder of the report was prepared by W. Burling Tucker (deceased), and R. J. Sampson, District and Assistant Mining Engineers, respectively, of the Mining Engineering Branch, State Division of Mines. Manuscript submitted for publication October 1948.

ABSTRACT

Kern County, organized in 1866, is in the south-central portion of the state, at the south end of the San Joaquin Valley. Bakersfield, the county seat, is approximately 95 miles north and 35 miles west of Los Angeles. Both the eastern and western portions of the county are mountainous; the central part lies in the San Joaquin Valley.

The western boundary of the county is on the east slope of the Coast Ranges which here are composed of Upper Cretaceous, upper Eocene, and lower and middle Miocene sediments, as shown on the geologic map of California.[1] Its southern boundary is in the Tehachapi Mountains which are composed largely of Jurassic granodiorite, and lower and middle Miocene sediments. The eastern portion includes the south end of the Sierra Nevada and part of the Mojave Desert. The Sierra Nevada is predominantly granodiorite. The exposures on the desert consist mainly of the Archean Rand schist, Jurassic acid intrusives, Tertiary volcanics and Miocene nonmarine sediments.

Kern County, as a result of its tremendous production of petroleum and natural gas, was the largest producer of minerals in the state in 1946. Value of its mineral production for that year was $133,082,652.00. Of this total, $126,047,828.00 was the production value for petroleum and natural gas; borates, brick, cement, clay, gold, gypsum, pumice, salt, silver, stone, tungsten ore, and volcanic ash accounted for the rest.

The mineral production from the county, including petroleum and natural gas, from 1880 through 1946 has aggregated $2,281,563,642.00. Los Angeles is the only county in the state which has exceeded this production.

Antimony occurs in many places in the county, usually in the form of stibnite, but some small deposits of the native metal have been found in the Havilah and Kernville districts. Production has been small.

Arsenic in the form of arsenopyrite has been found in several places in the county. Only one small shipment has been made.

Copper has been produced in small quantities from a few localities, principally the Kernville, Woody, and Rademacher districts.

Gold-silver ores are perhaps most numerous in their occurrence in the county but are largely confined to its eastern portion. The principal deposits are found in quartz veins in granodiorite, quartz monzonite, rhyolite, and schist. The most important producing areas are Mojave, Randsburg, Caliente Canyon, Piute Mountains, and Kernville.

Lead and lead-zinc ores are scarce in the county, occurring sparingly in Caliente Canyon and the Tehachapi Mountains east of Gorman. Production has been negligible.

Tungsten ores are widely distributed in the eastern portion of the county. They occur in placer deposits and in quartz veins in the Rand schist in the Randsburg area, in quartz veins in granitic rocks, and at the contact of the granite with limestone and schist in the Sierra Nevada, Piute and Greenhorn Mountains.

Tin has been found in the Tehachapi Mountains, on Tejon Ranch, 6 miles northeast of Gorman. Here cassiterite occurs in a limonitic gossan and crystalline limestone 500 feet from a contact of the limestone with a granitic rock. There has been no production.

Large deposits of tincal (borax) and kernite (rasorite) occur in Tertiary shale beds 5 miles north of Kramer, a station on the Santa Fe Railroad, 28 miles east of Mojave. The major portion of the world's supply of borates is produced here.

Cement is manufactured near Tehachapi by the Monolith Portland Cement Company.

Alluvial clay in the vicinity of Bakersfield has long been used for the manufacture of brick. Many thousands of tons have been taken from Rosamond and Muroc Dry Lakes for use in oil-well mud. Kaolinized rhyolitic material is shipped from Jawbone Canyon for use in the ceramic industry. Bentonite has been mined in the Kramer district.

Feldspar is produced from a pegmatite some 2 miles northwest of Rosamond.

Gypsum occurs in widely separated areas within the county. In the western portion near the foot of the east slope of the Coast Ranges, there are numerous deposits of gypsite, overlain by 1½ to 4 feet of soil. The gypsite, particularly that from the vicinity of Lost Hills and McKittrick, has been widely used as a soil conditioner. At the foot of the west slope of the Sierra Nevada, notably along Cottonwood Creek, extensive deposits occur, both as crusts and as interstratifications with the Quaternary and upper Pliocene sediments. Material from this deposit formerly was used for agricultural purposes. A deposit of granular gypsum occurs at the south end of Salt Dry Lake, about 20 miles north of Mojave. The material has long been used for

---

[1] Jenkins, O. P., Geologic map of California, scale 1:500,000, California Div. Mines, 1938.

fertilizer. Recent attempts have been made to utilize the rock gypsum in the Frazier Mountain area.

A perlite deposit in El Paso Mountains is being drilled to ascertain its extent.

Petroleum and natural gas have been produced in staggering quantities from the county. This production has come from 32 separate fields or pools which are located in or near the San Joaquin Valley region. The area in which they have been discovered extends from the eastern foothills of the Coast Ranges to the western foothills of the Sierra Nevada, a distance of approximately 67 miles, and from the foot of the Tehachapi Mountains to the north end of the county, a distance of 45 miles.

Pumice occurs in El Paso Mountains about 7½ miles north of Saltdale.

Volcanic ash (pumicite) forms extensive beds in El Paso Mountains. It was mined by Cudahy Packing Company for use in Old Dutch Cleanser until the fall of 1947. This had been a continuous operation for 25 years. Calsilco deposit has supplied material for Holly Cleanser for several years.

INTRODUCTION

Kern County, comprising 8,003 square miles, was organized in 1866. It is the third largest county in the state; only San Bernardino and Inyo Counties are larger. It is bounded on the north by Tulare, Kings, and Inyo Counties; on the south by Los Angeles and Ventura Counties; on the east by San Bernardino County; and on the west by San Luis Obispo County.

Because of its tremendously productive oil fields, it led all counties of the state in mineral production for many years, but from 1924-43, inclusive, it was surpassed by Los Angeles County. This was entirely the result of increased petroleum production in Los Angeles County.

The petroleum resources of Kern County have been intensively developed since 1900 and the industry has attained gigantic proportions. Production of borax north of Kramer, and the discovery and development of large gold ore bodies in Soledad Mountain and adjacent territory a few miles south of Mojave, have added materially to its mineral production.

Topography

The southern end of the Sierra Nevada is in the southeastern part of the county where it is connected with the Coast Ranges by the Tehachapi Mountains. The western boundary of the county follows the crest of the Coast Ranges.

The southern end of the San Joaquin Valley comprises about one-third of the area of the county. The southeastern slope of the Sierra Nevada and a portion of the Mojave Desert are included within its eastern boundaries. Along the northwestern border is the Diablo Range, rising to a height of 3,000 feet. Thus the area contains lofty mountain ranges, a wide and fertile valley, and a desert region.

Streams

Kern River and Poso Creek are the principal streams of the county. Kern River rises in the highest peaks of the Sierra Nevada in the northeastern end of Tulare County and flows southwestward for 125 miles into Kern County. It is one of the most important power-generating streams of the state. Beyond the mountains, it flows westward across the San Joaquin Valley, where it is divided into many channels, to provide water for irrigation.

Transportation

Two transcontinental railroads, the Southern Pacific and the Santa Fe, traverse the central portion of the county in a north-south direction.

A branch line of the Southern Pacific skirts the eastern foot of the Sierra Nevada from Mojave into Owens Valley. Excellent paved roads traverse the county in all but the more isolated areas, where there are secondary county roads.

MINERAL RESOURCES

Included in the developed and undeveloped mineral resources of the county are antimony, arsenic, asphalt, borax, clay, cement, copper, feldspar, gems, gold, gypsum, iron, lead, limestone, magnesite, marble, mineral paint, natural gas, perlite, petroleum, potash, pumice, salt, silica, silver, soapstone, soda, sulphur, tin, tungsten, volcanic ash, and zinc.

This report contains descriptions of mining properties discovered or active since 1933 when the last Division of Mines publication on Kern County was released [2]. A tabulation of these and older or inactive properties, together with the bibliography for each, is printed herein.

The mines are described in alphabetical order, in two sections, metallic and nonmetallic. Numbers following mine names refer to numbers on the accompanying map, plate 17.

Metallic Minerals

Antimony

Deposits of native antimony are very rare, but some have been found in the Havilah and Kernville districts of Kern County. Antimony in its most common form, the sulphide stibnite, occurs in many places in the county, notably in the mountains bordering San Emigdio Canyon in T. 9 N., R. 21 W., S.B.; about 12 miles northwest of Cantil and 22 miles north of Mojave in secs. 5 and 6, T. 30 S., R. 36 E., M.D.; and also 24 miles northwest of Rosamond in sec. 4, T. 10 N., R. 15 W., S.B.

Although there have been many small shipments from the various localities mentioned above, the total recorded production from 1880 to 1944 has amounted to approximately $80,000.

Alice antimony mine (1) comprises five claims in Havilah mining district, in sec. 2 ?, T. 28 S., R. 32 E., M.D., three-quarters of a mile north of Havilah, at an elevation of 3,400 feet. The owners are R. L. Coughran and Alice Coughran, Isabella, California. It is operated by Antimony Mines Company; R. C. Golden of Bodfish, California, is president.

Stibnite occurs in irregular masses in a mineralized zone in porphyry. Development consists of a tunnel 75 feet in length, and a winze 60 feet deep.

In 1940, the property was under lease to the Keturah Mining Company, M. E. Miller, president, 136 West Ninth Street, Long Beach, California. This company made several small shipments in 1939 and 1940 to Harshaw Chemical Company, El Segundo, California.

The property is now idle.

Amalia mine (2) consists of one claim (the Amalia) at Antimony Flats on a ridge between Jawbone and Lone Tree Canyons in sec. 5, T. 31 S., R. 36 E., M.D., 6 miles west of Cinco, at an elevation of 4,200 feet. In 1940 the property was operated by the Antimony Mines Com-

---

[2] Tucker, W. B., and Sampson, R. J., Gold Resources of Kern County: California Div. Mines Rept. 29, pp. 271-339, 1933.

PHYSICAL
SCIENCES
LIBRARY

Table 1. Mineral production of Kern County, 1880-1946

Year	Asphaltum		Brick		Copper		Fullers earth		Gold, value	Lime		Limestone		Silver, value	Natural gas		Petroleum		Miscellaneous and unapportioned		
	Tons	Value	M	Value	Pounds	Value	Tons	Value		Barrels	Value	Tons	Value		M cu. ft.	Value	Barrels	Value	Amount	Value	Substance
1880									$94,214					$390							
1881									100,000					14,000							
1882									260,000					20,000							
1883									150,000					5,000							
1884									100,000					5,000							
1885									72,003												
1886									94,640					1,721							
1887									72,358					150							
1888									60,000					2,500							
1889									242,676					7,517							
1890									117,341					556							
1891									107,735					61							
1892									107,736					73							
1893									83,665					1,754							
1894	6,900	$138,000							310,707	33,000	$28,500			39,700			11,215	$69,334	92 tons	$3,720	Antimony.
1895	1,400	28,000							231,433	25,400	24,950		$10,000	46,064			110	110	33 tons	1,485	Antimony.
1896	2,484	44,680							590,667	37,100	32,329	5,000	5,000	34,650			235	235	15 tons	2,250	Antimony.
1897	4,650	80,350	1,100	$6,600					754,313	53,400	70,370			10,471					25 tons	3,500	Antimony.
1898	1,850	50,000	2,000	14,000					1,017,930	42,000	29,900			6,543			10,000	10,000	220 tons 40 tons 27 tons	1,100 1,200 3,382	Coal. Antimony. Borax.
1899	2,537	57,670	1,600	11,400			620	$12,400	863,414	64,700	57,690			6,810			15,000	13,500			
1900	701	14,020	2,525	17,300	4,000	$750	500	3,750	865,252	57,721	51,700			147,736			919,275	827,348		859,927	Unapportioned, 1900-09.
1901	3,112	43,126	4,600	23,400	429,248	67,606	1,000	19,500	1,007,659	92,000	82,700			40,497			3,902,125	1,131,610	1,600 lbs. 50 tons	54 8,350	Lead. Antimony.
1902	10,150	101,500	3,500	24,500	235,840	27,122	987	19,246	1,165,982	90,360	80,856			99,135			9,777,948	1,955,585	1,000 tons	8,000	Gypsum.
1903	8,006	100,787	9,000	30,000	4,300	559	250	4,750	1,022,353	101,661	76,246			114,614			18,001,148	3,600,230	28 tons 1,000 tons	63 8,000	Bituminous rock. Gypsum.
1904	12,451	124,110	700	4,900			500	9,500	1,426,523	178,038	172,000			151,189			19,608,045	3,431,408			
1905	10,580	105,860	750	6,000					1,100,971	279,650	255,500		44,000	134,944			17,069,715	3,174,066	53 tons 1,350 tons 52 tons	54 11,000 18,800	Clay. Gypsum. Tungsten.
1906	23,136	231,360	4,275	34,200					800,117	295,013	207,096			129,503			13,628,000	3,765,200	215 tons	752 183,600	Clay. Tungsten.
1907	20,443	200,158	2,168	18,428					878,798	175,000	169,822			86,033			15,700,308	4,673,867	1,000 tons	6,500	Gypsum.
1908	50,000	475,000	2,080	19,552					827,087	116,717	87,788			96,550			18,777,871	9,388,935	500 tons	2,000	Gypsum.
1909	54,599	655,391	3,385	29,634			359	5,385	654,799	115,709	88,869			101,633	38,000	$2,714	24,549,758	12,585,240	 1,700 tons 4,781 lbs.	500 8,300 174	Gems Gypsum Lead.
1910	76,605	811,846	8,332	63,711					610,974	99,187	86,198		4,331	35,041	975,724	47,364	40,641,159	17,825,212	1,075 tons 160,000 tons 242 tons	8,365 112,000 121	Gypsum. Rubble. Clay.
1911			5,603	41,426	29,441	3,680			657,471	90,500	82,025	600	400	5,833	1,654,350	165,438	40,562,825	20,207,906	230,950 tons 853 tons 2,417 lbs.	107,880 4,245 109	Crushed rock. Gypsum. Lead.
1912			1,690	23,120					830,421	162,831	124,894			11,480	4,400,000	325,484	61,448,067	21,762,532	8,479 tons 10,664 lbs.	18,188 885	Gypsum. Lead.
						Total	4,210	$74,531													
							Miscellaneous stone,[2] value														
1913			1,625	22,000	3,498	542			649,712	135,000	91,200			11,851	7,111,237	568,609	58,698,432	27,038,474	208 tons 10,000 tons 1,370 lbs.	104 22,750 61 600	Clay. Gypsum. Lead. Other minerals.
1914			3,834	29,214	7,394	983			594,337	81,000	65,100			8,002	9,508,868	390,532	65,332,833	26,721,046	346 tons 82 tons 379 lbs. 20,000 tons	172 320 15 50,000 180,575	Clay. Gypsum. Lead. Salt. Other minerals.
1915					1,047	163		$59,319	983,319	65,176	39,523	1,425	1,710	13,310	12,163,461	737,638	54,810,669	23,184,913	267 tons 84,371 lbs.	11,301 3,965 299,907	Antimony ore. Lead. Cement, pottery clay, fullers earth, gypsum, magnesite, salt, tungsten.
1916			3,177	23,824	24,764	6,089		93,723	747,042	①				8,475	16,679,658	1,379,033	54,120,509	34,691,246	145 tons 24,274 lbs. 4,100 tons 103 tons	5,880 1,676 30,047 23,700 482,387 363,516	Antimony ore. Lead. Lime and limestone. Silica. Tungsten concentrates. Cement, clay, feldspar, fullers earth, magnesite, quicksilver, salt.
1917			and tile	22,785	251,225	98,584		31,787	537,852	①		①		7,813	25,819,376	1,445,850	53,065,066	47,387,104	113 tons 9,084 lbs. 300 flasks 40 tons	16,041 833 27,250 58,148 139,345	Antimony ore. Lead. Quicksilver. Tungsten concentrates. Clay, feldspar, lime, limestone, magnesite, salt.
1918			1,678	16,380	95,580	23,608		311	246,127	23,615	23,615	①		7,617	23,545,128	1,507,012	49,049,017	61,410,496		174,419	Lead, limestone, magnesite, manganese, quicksilver, salt, tungsten.
1919			1,709	175,112				29,320	150,589	86,952	112,724	①		8,402	25,363,739	1,618,913	47,734,035	64,440,947	17,000 tons	81,000 9,345	Salt. Fullers earth, limestone, quicksilver.
1920			3,650	56,550	200	38		31,180	61,187	76,395	106,733			8,385	34,912,865	1,810,147	60,660,438	80,831,991	22,000 tons 3,060 tons	87,000 20,100 108,270	Salt. Silica. Cement, gems, lead, quicksilver.
1921			5,840	85,620				36,268	84,698	72,629	141,401			1,897	40,136,930	1,926,787	67,434,945	97,630,407	18,500 tons	93,500 829,115	Salt. Cement, gypsum, limestone, silica.
1922			6,082	66,652				35,585	124,337					6,524	47,644,633	2,282,100	53,512,157	64,803,222	18,000 tons	66,000 1,106,582	Salt. Cement, copper, lime, silica, lead.
1923			5,271	68,375				9,225	107,651	17,985	214,163	①		33,151	42,421,592	2,651,656	45,952,794	37,629,300	18,921 tons	97,336 1,602,138	Salt. Cement, clay (pottery), gypsum, limestone, pumice, sulphur.
1924			①	23,058				5,244	164,132	6,130	96,880			35,902	47,881,308	2,622,651	61,178,405	69,572,934	10,508 tons	44,115 23,058 1,709,635	Salt. Brick and clay (pottery). Arsenic, cement, copper, lead, pumice, sulphur.
1925			①					3,000	135,545					7,465	45,649,845	2,290,608	58,852,742	84,255,094	6,890 tons	28,658 2,680,160	Salt. Antimony, borates, cement, brick, clay (pottery).
1926			4,591	55,140				28,000	135,508	①				4,067	44,182,140	2,158,867	54,549,646	78,987,687	11,279 tons	41,116 2,144,880	Salt. Cement, feldspar, fullers earth, gypsum, lime, pumice, silica.
1927			,835	50,438				79,510	171,100	①				6,032	39,401,478	2,057,807	51,570,412	58,738,699	14,900 tons	69,839 3,553,163	Salt. Borates, cement, clay (oil-well mud), copper, feldspar, gypsum, lime, onyx, pumice.
1928			2,126	30,791				78,663	180,453	①				5,245	35,107,062	1,916,797	44,090,638	38,803,054		4,043,778	Antimony, borates, cement, clay (pottery), feldspar, fullers earth, gypsum, lime, pumice, salt.
1929			3,503	44,681				361,696	148,421					2,312	34,409,095	1,861,050	43,577,420	32,299,584	58,551 tons	85,845 4,004,550	Clay (pottery). Borates, cement, fullers earth, volcanic ash, quicksilver, salt, tungsten.
1930			①		①			450,351	165,435					1,757	27,908,423	1,290,000	44,170,816	37,015,139	111,301 tons 371,123 tons	2,335,190 117,834 1,612,181	Borax. Clay. Brick, cement, copper, feldspar, fullers earth, gems (rose quartz), gypsum, lead, quicksilver, salt, volcanic ash.
1931			①		207	19		108,958	202,108					2,634	26,977,942	1,444,732	35,704,138	22,765,072	27,409 tons 6,307 lbs.	46,668 233 4,212,034	Clay (pottery and oil-well drilling). Lead. Bentonite, borates, brick, cement, feldspar, gypsum, mineral water, volcanic ash, quicksilver, salt.
1932			①		①			49,077	296,250	①		①		3,957	26,234,262	1,201,293	35,552,581	23,393,585	14,770 tons	22,871 3,102,892	Clay (pottery and oil-well drilling). Bentonite, borates, brick, cement, copper, lead, volcanic ash, salt.
1933			①		760	49		70,931	424,376					70,031	20,571,398	916,090	35,349,272	23,521,406		2,031,110	Bentonite, borates, brick, cement, clay (pottery), gems, lead, volcanic ash, quicksilver, salt, wollastonite.
1934			①		5,502	440		131,743	1,021,849					73,468	21,309,723	1,017,661	41,823,494	30,475,225	19,526 tons 11,008 lbs.	30,142 407 4,302,252	Clay (pottery). Lead. Bentonite, borates, brick, cement, gems, volcanic ash, quicksilver, salt, tungsten ore, wollastonite.
1935			①		37,971	3,152		124,360	1,391,646					165,978	36,059,134	1,891,675	54,723,481	39,905,553	2,180 lbs.	87 3,521,938	Lead. Borates, brick, cement, clay, volcanic ash, salt, tungsten.
1936			①		1,402	129		184,606	2,401,280					295,591	58,044,172	3,240,196	62,273,932	53,781,287		5,435,585	Bentonite, borates, brick, cement, clay, lead, gypsum, mica schist, volcanic ash, quicksilver, salt.
1937			①		5,504	666		237,757	2,465,134					561,712	65,142,854	3,950,521	69,878,714	61,905,918	42,628 tons 2,923 lbs.	130,452 172 4,909,821	Clay (oil-well drilling mud). Lead. Borates, brick, cement, volcanic ash, quicksilver, salt, tungsten ore.
1938			①		①			240,750	3,034,605					742,256	68,974,794	4,244,897	66,093,496	58,603,255	38,010 tons 6,994 lbs.	64,821 322 4,397,668	Clay (oil-well drilling mud). Lead. Borates, brick, calcium silicate, cement, volcanic ash, quicksilver, salt, copper.
1939			①		①			158,220	3,151,015					767,633	73,950,832	5,191,065	58,893,565	48,604,001	23,213 tons 28,542 lbs.	32,373 1,341 4,140,039	Clay (pottery and oil-well drilling mud). Antimony, bentonite, brick, calcium silicate, cement, copper, gypsum, quicksilver, salt, tungsten ore, volcanic ash.
1940			①		2,617	296		282,576	2,887,255					591,608	79,409,481	4,257,590	60,680,165	50,835,439	42,298 lbs. 27,133 lbs. 70,043 tons	6,062 1,357 93,964 3,599,585	Antimony. Lead. Gypsum. Bentonite, borates, brick, calcium silicate, cement, clay, volcanic ash, quicksilver, salt.
1941			①		5,164	609		347,459	2,800,960					617,381	91,807,125	4,573,754	65,028,935	37,607,724	69,671 tons 31,559 lbs. 112,088 tons 4,414 units	242,547 1,801 203,506 114,754 4,344,033	Clay (pottery and oil-well drilling mud). Lead. Gypsum. Tungsten ore. Antimony, bentonite, borates, brick, calcium silicate, cement, volcanic ash, salt, quartz.
1942					2,172	263		449,160	1,991,990					425,010	70,590,547	3,431,558	72,093,741	64,477,255	71,172 tons 156,104 tons 2,591 units	118,694 206,659 61,652 4,365,607	Clay (pottery and oil-well drilling mud). Gypsum. Tungsten ore. Antimony, bentonite, borates, cement, volcanic ash, salt, silica (quartz).
1943			①		2,726	354		190,064	103,705					7,281	65,576,727	3,395,175	84,034,943	86,174,073	96,619 tons 250,989 tons 2,112 units 14,214 lbs.	261,243 335,049 57,697 1,535 3,715,283	Clay (pottery and oil-well drilling mud). Gypsum. Tungsten ore. Zinc. Bentonite, borates, brick, cement, lead, volcanic ash, salt.
1944			①		①			222,606	45,185					754	72,111,360	3,786,075	92,094,311	98,829,308	152,237 tons 292,306 tons 7,142 lbs. 306 units 8,532 lbs.	522,711 394,356 571 7,390 973 4,447,413	Clay (pottery and oil-well drilling). Gypsum. Lead. Tungsten ore. Zinc. Antimony, bentonite, borates, brick, cement, copper, volcanic ash, salt, tin ore.
1945					①			156,507	31,990					386	76,648,176	3,972,990	110,290,276	116,846,28[illegible]	168,925 tons 11,897 lbs.	711,676 1,368 4,994,872	Clay (pottery and oil-well drilling). Zinc. Borates, cement, copper, gypsum, lead, volcanic ash, salt, tungsten ore.
1946			①					327,259	94,710					6,972	72,945,848	5,694,426	100,640,406	120,353,402	177,980 tons 208,162 tons	544,841 352,484 5,704,558	Clay (pottery and oil-well drilling). Gypsum. Bentonite, borates, brick, cement, pumice, volcanic ash, salt, tungsten ore.
Totals	289,610	$3,327,858	196,609	$1,138,991	1,150,558	$205,721		$4,586,445	$45,010,704	2,053,069	$2,758,912	17,025	$65,441	$5,812,542	1,490,599,317	$82,574,875	2,276,511,208	$2,032,193,457		$102,935,707	

Grand total value $2,280,685,244

---

[1] See under Unapportioned.

[2] Includes crushed rock, rubble, rip-rap, sand, gravel.

PHYSICAL
SCIENCES
LIBRARY

A bra
Neva
the c
count

]
count
spar,
eral
silver

or ac
Coun
erties

lic ar
the a

Antin

]
in th
most
coun
N., R
of M
north

local
1944

distr
nortl
Coug
Anti
dent.

phyr
60 fe

pany
forn
Hars

Flat
S.,]
feet.

Div.]

pany; R. C. Golden, of Bodfish, California, was president. The mine was operated also in 1917 and 1918, but is now idle.

Development consists of shafts and open cuts. The mined ore was hauled to a mill near Gypsite. Several shipments of stibnite were made to Harshaw Chemical Company, El Segundo, California.

Antimony Peak (4) (San Emigdio) is in secs. 9 and 10, T. 9 N., R. 21 W., S.B., on the south slope of Antimony Peak, about 12 miles northwest of Frazer Mountain Park. The owner is Kern Land and Development Company, Bakersfield, California. This land, now patented, is one of the oldest mineral locations in Kern County.

In 1940-41 the U. S. Bureau of Mines prospected the top and south slope of this peak with a number of trenches. The work disclosed a shear zone in quartz diorite which trends northwest and dips 58° W. At the top, at an elevation of 6,400 feet, the zone is 50 to 100 feet wide, but at the 600-foot tunnel, at an elevation of 5,850 feet, it is 4 to 20 feet wide. No continuous ore shoot was found.

Jennette-Grant antimony deposit (5). A deposit of antimony has been developed on the Jennette-Grant Mining Company's property on the west slope of the Piute Mountains in the Green Mountain mining district, 12 miles south of Weldon in sec. 10, T. 28 S., R. 34 E., M.D., at an elevation of 5,700 feet. The owner is Jennette-Grant Mining Company; George Bergner of Harrisburg, Pennsylvania, is president; and U. C. Anderson, of Los Angeles, is manager.

On the ridge north of the Jennette-Grant crosscut tunnel, stibnite occurs in a vein of calcite and quartz at the contact of limestone and schist. The vein strikes northwest and can be followed along its outcrop for several hundred feet. It is developed by a tunnel driven 70 feet northwest on the limestone, schist and slate contact.

The deposit was worked in 1917-18, and some shipments were made during this period.

The property is now idle.

Studhorse Canyon antimony mine (7) comprises four claims situated on a ridge south of Studhorse Creek in sec. 5, T. 31 S., R. 33 E., M.D., 6 miles south of Loraine Post Office at an elevation of 5,600 feet. The owners are Jessie L. Stubblefield and R. Ramey, of Caliente, California.

Stibnite occurs in irregular masses in a vein 6 feet wide. Several small shipments were made to Harshaw Chemical Company, El Segundo, California, but the property is now idle.

Wiggins antimony mine (10) comprises two claims at an elevation of 5,000 feet in sec. 8, T. 31 S., R. 33 E., M.D., on a ridge near the headwaters of Studhorse Creek, 6 miles east of Keene. The owners are A. B. McAdams and J. M. Wiggins, Mojave, California.

A 3- to 4-foot vein of antimony occurs in granite. It is developed by a 75-foot tunnel and open cuts along the outcrop of the vein. In 1918, 62 tons of ore was shipped.

The property is now idle.

Arsenic

Arsenic is found in a number of localities in the county. It occurs in the form of arsenopyrite (FeAsS) and scorodite ($FeAsO_4.2H_2O$), an oxidation product of arsenopyrite. A small shipment was made from the Contact mine in 1924.

Copper

Copper occurs in a few widely separated areas in the county, notably near Kernville and Woody, on the western slope of the Sierra Nevada, in the Rademacher district, and in El Paso Mountains. No copper ore is being mined in the county at present.

Apache mine (Holland) (12) comprises six claims situated in the Goler mining district in El Paso Mountains, in sec. 32, T. 28 S., R. 39 E., M.D., 8 miles north of Goler, a siding on the Owens Valley Branch of the Southern Pacific Railroad, at an elevation of 3,000 feet. The owner is L. B. Williams, 6127 Sepulveda Boulevard, Van Nuys, California.

A dike which strikes east occurs in basalt. The dike contains malachite, chalcopyrite, pyrite, and some gold and silver, and ranges from 10 to 15 feet in width. Development consists of a tunnel driven west approximately 350 feet.

The property is now idle.

Copperola Group of Mines (13). The Copperola group comprises the following claims: Run Around Nos. 1 to 8, Run Around Extension Nos. 1 and 2, Run Around millsite, Copperola Nos. 11 and 12, Copperola Nos. 1 and 2, and Zuna group (Zuna A, and Zuna Extension); all situated in the Goler mining district, in El Paso Mountains, in secs. 12 and 13, T. 29 S., R. 38 E., M.D., 12 miles northeast of Randsburg and 3 miles north of Garlock, at an elevation of 3,500 feet. The owner is Della G. Gerbracht, Randsburg, California. The property is under lease to R. L. Meuer, Los Angeles. A series of parallel quartz veins in monzonite, strike northwest and dip 45°-80° E.; they range in width from 6 to 15 feet. The metallic minerals are azurite, malachite, and chalcopyrite with gold and silver.

On Zuna A claim the quartz vein in the quartz monzonite strikes east, dips 45° N., and has a width of 6 feet. A shaft has been sunk on the vein to a depth of 160 feet. A shipment of 30 tons was made to a smelter.

On Copperola No. 1 and No. 2 claims a massive outcrop of quartz strikes N. 40° W. and dips 60° SW. A 100-foot trench across the outcrop exposed four quartz veins in quartz diorite. A shaft has been sunk on the middle vein to a depth of 50 feet. The quartz carries azurite, malachite, and chalcopyrite.

The property is now idle.

Copper Basin group of mines (14) in the Goler mining district in El Paso Mountains adjoining Copperola group on the west, comprises 24 claims situated in sec. 15, T. 29 S., R. 38 E., M. D., 12 miles northeast of Randsburg and 3 miles north of Garlock, at an elevation of 3,700 feet. The owner is William Schmidt, of Randsburg.

A series of parallel quartz veins in granite strike northwest and dip 45°-70° E. The widths range from 4 to 6 feet. The group is developed by a tunnel 600 feet in length.

The property is now idle.

Orange Blossom mine (17) comprised of eight claims, Orange Blossom No. 1 to No. 8, is located on the southeast slope of El Paso Mountains, in sec. 6, T. 30 S., R. 38 E., M. D., 3 miles northwest of Gypsite, a siding on the Southern Pacific Railroad, at an elevation of 2,500 ft. The owners are Mrs. Josie Bishop, A. H. Bishop, and H. D. Cook of Mojave.

A gossan outcrop, which occurs in schist, is 10 to 15 feet wide and 15 feet long, strikes N. 20° W., and dips 60° W. The limonite contains azurite and malachite and some gold. On the footwall side of this outcrop is another lens of gossan about 20 feet in length and 5 feet in width. Here the limonite is stained with copper oxides. On the hanging-wall side of the outcrop is a quartz vein 2 feet wide, which strikes N. 25° W. and dips 70° W. This vein can be followed for 1,500 feet to the head of Bonanza Canyon. A tunnel has been driven N. 25° W. 75 feet under the first gossan outcrop. The footwall is diorite, and the hanging wall is schist. Other developments consist of shallow open cuts along outcrops. At a lower elevation on the west side of a gulch, gossan 60 feet in width crops out. It contains azurite and malachite and some gold. Deposits in the gulch below have been worked as placers.

The main development work has been on Gold Blossom No. 3 claim. A shaft has been sunk on the vein to a vertical depth of 85 feet. The quartz vein developed had an average width of 3 feet. Orange Blossom claim No. 8 is in sec. 1, T. 30 S., R. 37 E., M. D., and adjoins Cash Register No. 4 quartz claim, which is owned by J. D. Voss and Company.

The property is idle.

Silverado copper group (18) comprises three claims in sec. 9?, T. 27 S., R. 33 E., M.D., 4½ miles south of Isabella, at an elevation of 3,500 feet. The owner is J. L. Hooper, of Hobo Hot Springs.

A granitic dike mineralized with chalcopyrite and pyrite occurs between schist and granite; the strike of the dike is northwest. The ore developed is reported to contain as much as 6 percent copper. An average sample is said to assay 1½ percent copper, 0.02 to 0.03 of an ounce of gold, and 1 ounce of silver.

Development consists of a shaft 40 feet deep, and a crosscut tunnel 20 feet in length with a drift 20 feet in length; there are also a number of surface trenches along 1,000 feet of the outcrop.

These claims are idle.

Zundra group (16) of three claims is in El Paso Mountains in sec. 12, T. 29 S., R. 38 E., M. D., 12 miles northeast of Randsburg and 3 miles north of Garlock, at an elevation of 3,500 feet. It is owned by Della Gerbracht, Randsburg, and leased to D., R. D., and Clarence D. Weiss, 1145 North La Mar, Burbank, California.

The country rocks are monzonite, limestone, and mica schist. A quartz vein in the monzonite strikes N. 40° W. and dips about 65° SW. Near the top of a hill a short open cut exposed a lens of ore some 6 feet wide. The metallic minerals are bornite and some chalcopyrite. A tram 800 feet long was built up to this open cut. Seven tons of ore were shipped.

It is reported that the owners are starting a 500-foot crosscut to pick up this ore at depth.

The group of claims is idle.

Gold-Silver

Gold was first discovered in Kern County in Greenhorn Gulch near the Kern River in 1851 by a member of General Fremont's party. Actual mining began with the discovery of the Keyes and Mammoth mines in 1852. Between that date and the end of 1944 production in the county amounted to $44,883,974 in gold.

Brief descriptions of the various gold-mining districts of the county have been published in previous reports.[3]

Amy group of mines (21) (Gold State) comprising five claims, is in secs. 5 and 22, T. 29 S., R. 34 E., M.D., in the Green Mountain district, 9 miles north of Piute. The elevation is 6,300 feet. The owners are Ed George and Martin J. Erricart of Piute, California. This is an old property relocated by M. J. Erricart in 1900. It had previously been operated by McKay and Statin who used a steam arrastre for extraction of the gold.

Six parallel veins occur in granite, striking N. 70° E. and dipping 70° S. The width of the veins ranges from 6 inches to 3 feet.

One tunnel has been driven 655 feet southwest on a vein, at an elevation of 6,335 feet. Five hundred forty feet from the portal, a winze was sunk 70 feet on the vein. In these workings an ore shoot 120 feet long and 30 inches wide was developed, which reportedly ran $80 per ton. It was stoped to the surface, a distance of 80 feet. At 470 feet from the portal, a raise connects with a crosscut tunnel driven from the south side of the ridge, a distance of 150 feet.

The last work here was the driving of a tunnel west, at an elevation of 6,250 feet, which was intended to pick up the ore shoot.

Mill equipment consists of a 9- by 7½-inch Blake crusher, a 10-ton Gibson gyratory mill, and a Myers concentrator. All are run by a 10-horsepower gas engine.

The property is now idle.

Beauregard Extension mine (26) in sec. 28, T. 25 S., R. 33 E., M.D., 1½ miles north of Kernville, comprises two claims in the Cove mining district at an elevation of 3,000 feet. It adjoins the Lady Belle mine on the northwest and is west of the Beauregard mine. The owners are Richard Boyd and Leonard Dimoush of Kernville, California.

The vein, which occurs in granite, is 4 feet in width, strikes N. 50° W., and dips 75° NE.

Development consists of a shaft sunk on the vein to a depth of 240 feet, with levels at 80, 160, 200, and 240 feet. A tunnel, driven 100 feet on the vein, connects with the shaft at the 80-foot level; a drift 100 feet to the northeast connects at the 160-foot level; a drift 50 feet to the southeast connects at the 200-foot level; and a drift 80 feet to the southeast and 50 feet to the northeast connects at the 240-foot level. The ore shoot developed is 80 feet in length.

The mine equipment consists of a 25-horsepower single-drum hoist and portable compressor. Ore is trammed from the shaft to a 25-ton ore bin, then to a 6- by 8-inch jaw crusher. Products from the crusher go to two Straub stamp mills, to 4- by 8-foot amalgamation plates, and thence to an Economy concentrator.

This property is idle.

Beryl group of mines (28). The Beryl group comprises 11 claims situated in the Red Rock Canyon mining district in sec. 30, T. 29 S.,

---

[3] Tucker, W. Burling, and Sampson, R. J., Gold resources of Kern County: California Div. Mines Rept. 29, pp. 278-286, 1933.

R. 37 E., M.D., 29 miles north of Mojave, at an elevation of 3,600 feet. The owner is Mrs. Josie Bishop of Mojave, California.

Three parallel quartz veins in rhyolite strike north and dip 70° E. The widths range from 4 to 10 feet. The principal development work has been on the Beryl No. 6 claim, formerly known as the Badger claim. Here a shaft has been sunk to a depth of 80 feet in a rhyolite porphyry dike, and at the bottom of the shaft a crosscut has been driven east and west. The rhyolite porphyry dike, which occurs in granite, is about 100 feet in width, strikes N. 10° W., and is iron-stained. Quartz outcrops 2 to 6 feet in width occur at intervals along the dike. The vein quartz is mineralized with pyrite, arsenopyrite, and chalcopyrite, and is reported to contain gold.

On Beryl No. 1 claim, a vein of quartz 8 to 10 feet wide strikes N. 10° W. and dips 70° E. The Hess shaft has been sunk on the vein to a depth of 35 feet. Vein quartz is mineralized with pyrite and chalcopyrite, and is reported to contain gold and silver. On the same quartz vein near the top of the hill, the Smith shaft has been sunk to a depth of 20 feet. The other claims have also been developed by open cuts and shallow shafts.

It is reported by the owner that ore samples extracted from Badger shaft show radioactivity.

These mines are idle.

Big Blue mine (29). This property includes the Beauregard, Lady Belle, and Sumner group of mines, totaling approximately 210 acres, situated in the Cove mining district, half a mile north of Kernville at an elevation of 2,900 feet. The owner is the Kern Development Company; C. S. Long, Hayward, California, is president. The property is under lease and bond to Kern Mines, Incorporated, of which Roland Toggnazzini is president, Walter Batec, 605 Market Street, San Francisco, secretary, and John W. Prout, Jr., 321 South Rodeo Drive, Beverly Hills, California, consulting engineer.

This is an old property which has been operated intermittently since the middle sixties. From incomplete reports, its production up to 1933 has been estimated at $1,746,910. The ore apparently ranged in value from $8.00 to $40.00 per ton. The property was in operation from 1935-43, when it was shut down by Order L 208 of the War Production Board. Total production figures are not available, but they exceed those given above.

The geology has been described in detail by Prout.[4] In general, it may be said that the Big Blue-Sumner lode, from which the greater part of the production has come, occurs in a shear zone along an alaskite-granodiorite contact which strikes N. 30° W. and dips 70° W. This lode has a maximum width of 125 feet. The principal mineralization, as much as 60 feet in width, is in the hanging wall or west vein; and in the footwall branch, which is 6 to 8 feet in width. The material between is silicified and contains some pyrite and arsenopyrite. Another system of veins known as the Lady Belle-Jeff Davis group is in the hanging wall of the Big Blue shear zone. These veins have a general strike of N. 69° E. and a northerly dip. They are neither as wide nor as persistent as those in the Big Blue system.

---

[4] Prout, John W., Jr., Geology of the Big Blue group of mines, Kernville, California: California Div. Mines Rept. 36, pp. 379-421, 1940.

Aside from numerous short tunnels and shallow shafts, principal development has been through the Sumner shaft, sunk about 400 feet on the Big Blue vein with levels at 80, 160, 260, and 300 feet. The Big Blue main working shaft, sunk about 510 feet at an inclination of 82° W., with levels at 80, 160, and 260 feet, connects with old workings, and with new levels at 360 and 460 feet. The Big Blue drainage tunnel was driven more than 2,000 feet to connect with the Sumner shaft. It is called the 260 level. The Graveyard or south tunnel is 500 feet long and intersects the Big Blue shear zone about 650 feet south of the Big Blue shaft. Total underground workings (most of which are now caved) probably have exceeded 5 miles.

The last operators developed four ore shoots on the 360-foot level, which ranged from 4 to 60 feet in width and from 200 to 540 feet in length. On the 460-foot level (1948) two of these shoots had been opened. One was 500 feet long and as much as 60 feet in width; the other, 200 feet long and 6 feet wide.

The Big Blue is a two-compartment shaft through which the ore is hoisted in a 3-ton skip by a 150-horsepower electric hoist, which dumps into a 100-ton bin. The ore then goes to an 18- by 20-inch jaw crusher, then to a belt conveyor and bin of 200 tons. Trucks haul it to the mill.

From the truck-bin the ore passes over a three-fourths inch grizzly; the oversize goes to a Traylor 8 B.H. reduction crusher and is crushed to three-fourths inch. The crusher product with grizzly undersize is hoisted by elevator to a cylindrical storage bin. By belt feeder it is delivered to a 6- by 8-foot Traylor ball mill, which is in closed circuit with a jig and classifier. The hutch product from the jig is reground in an amalgamating barrel, and rejects are returned to the classifier. Overflow from the classifier is pumped to a surge tank, thence to five rougher flotation cells; froth from the four cells goes to a cleaner cell. Froth from the first cell and cleaner cell goes to concentrates; tailing from the cleaner cell goes to a mill circuit; tailing from rougher cells goes to six scavenger cells; the froth goes to a mill circuit; and tailing to the tailing-pond. About 45 percent of recovered gold is caught by the jig. Recovery of 94 to 97 percent is reported. Capacity is about 150 tons per day. Power is supplied by the Southern California Edison Company.

The mine has been idle since the early part of 1943.

Big Dyke mine (30), comprising five claims, is in the Rand Mountains on the west side of Fiddlers Gulch, 1 mile south of Randsburg. The owners are George Benko of Randsburg, and the Shay and Miller Estates. It is under lease to C. O. Wise of Randsburg.

The vein on the contact of monzonite and Rand schist strikes north, dips 40° E., and ranges from 2 to 12 feet in width. Monzonite forms the hanging wall. A rhyolite dike striking approximately east occurs in both the schist and monzonite. It crosses the contact a few feet south of the shaft, where it is displaced about 35 feet in a northward direction by a fault.

Development consists of a 46 degree inclined shaft sunk 300 feet, with levels at 90, 200, and 300 feet. On the 90-foot level a drift extends 200 feet south; on the 200-foot level, a drift extends 200 feet north and 200 feet south; and on the 300-foot level, a drift extends 100 feet north, and 200 feet south. There is also a crosscut which extends 140 feet east in the dike on the 90-foot level. On the 300-foot level about 60 feet north of the shaft, a crosscut extends 60 feet west.

About 30 feet south of the shaft where the vein crossed the dike, a small shoot of ore yielding $83 per ton was taken out. The vein has been stoped in the 200 feet south of the shaft from the 300- to the 100-foot levels. The vein has also been stoped in the 100 feet north of the shaft from the 200- to the 100-foot levels.

Present operators are working in the 90-foot level south of the shaft. Seventy feet from the shaft they crosscut 25 feet west to the footwall and raised 25 feet, where they have mined 100 tons from the vein which is 3 to 6 feet wide. They have also raised 40 feet into the hanging wall at a point opposite the footwall crosscut.

Ore is treated in the Butte mill about half a mile north of the mine. The equipment consists of a 110 cubic foot compressor and a 15-horsepower gas hoist.

Two men are working.

Big Gold mine (31) (West End). There are five claims in this group. They are on the west slope of the Rand Mountains in secs. 3 and 4, T. 30 S., R. 40 E., M.D., 3 miles southwest of Randsburg. The owner is John Kreta of Randsburg.

At least two veins have been found on this property. Big Gold vein strikes N. 20° W. and dips 40° E. It has the Rand schist on the footwall and a monzonite hanging wall. The vein filling is quartz carrying free gold, pyrite, and scheelite. It averages about 4 feet in width, although in places it was as much as 12 feet. The second vein is about 20 feet in the hanging wall of the Big Gold vein and roughly parallel to it. It accompanies a rhyolite dike. The vein filling is quartz, but the mineralization of gold and scheelite appears to penetrate the rhyolite, which is cut by the vein. The vein ranges from 1 to 6 feet in width. The scheelite seems to be concentrated near the hanging wall.

Development consists of a two-compartment vertical shaft 365 feet deep. The shaft intersected the Big Gold vein at the 150-foot level and drifts were driven 200 feet south and 30 feet north. The vein was stoped for a length of 40 feet across a 12-foot width. A winze was sunk 105 feet from the 150-foot level. Eighty feet south of the shaft, a crosscut was driven east for 25 feet where it intercepted the hanging wall vein. A drift was driven 47 feet south on this vein to a north-trending fault that dips 80° E. In the crosscut, 15 feet east of the drift, is a 30-foot winze on a 45° inclination, from which a drift runs 105 feet southward. The last 85 feet of this drift was underhand stoped for 35 feet on the dip. The ore averaged about 3 feet in width. Ore from this stope (700 tons) averaged $39.10 gold per ton. From a 42-foot winze at the east end of this stope a drift has been run north 40 feet at the bottom. On the 250-foot level a crosscut run 85 feet east intersected a vein, on which a drift was driven 90 feet south.

The owner has erected a mill at his home in Randsburg consisting of the following: A 25-ton bin, a 6- by 8-inch jaw crusher, an elevator, and a quarter-inch screen. Oversize goes to a small jaw crusher and a three-sixteenths inch screen. Oversize from this goes to 6- by 9-inch rolls, then to an elevator and a 3-foot Herman ball mill. Three cyanide leaching tanks 8 feet in diameter and zinc boxes are used for further treatment. Capacity is about 12 tons per day.

Black Hawk mine (32), consisting of 130 acres, is in the Rand mining district, 3 miles southwest of Randsburg. The owner is George H. Clapp, Sewickley, Pennsylvania.

This property was operated, with a few interruptions, from 1896 to 1942.

Three parallel quartz veins occur in the schist, striking north and dipping 50° E. The widths of the veins range from 18 inches to 3 feet. The ore is free milling and of good grade, ranging in value from about $12 to $60 per ton. The average is well above the lower figure. Production has been about $700,000.

The principal development consists of a shaft sunk on the vein 600 feet, with levels at 100, 200, 250, 450, 500, and 600 feet. The total development is approximately 8,000 feet.

The shaft is equipped with a 20-horsepower electric hoist, a compressor, etc. A five-stamp amalgamation mill is on the property.

The mine is idle.

Blue Eagle Mine (48). See Cactus Queen.

Blue Jay mine (34) comprises two claims in the Green Mountain mining district in the Piute Mountains in sec. 31, T. 28 S., R. 34 E., M.D., 10 miles south of Weldon, at an elevation of 7,000 feet. The owner is John Wyeis of Bodfish, California. A 2-foot quartz vein in granite strikes northeast and dips 70° NW. A tunnel is driven northeast on the vein 150 feet to the shaft, which is 50 feet in depth.

This mine is idle.

Bowman mine (37) (French Meadows), comprising three claims in the Green Mountain mining district, is in sec. 20, T. 28 S., R. 34 E., M.D., 1 mile north of French Meadows and 8 miles north of Piute, at an elevation of 7,100 feet. The owner is J. W. Walters of Isabella, California.

Mineralization is in a quartz vein 6 inches to 2½ feet wide, striking N. 70° E. and dipping 70° S., in granite. The vein quartz carries free gold, pyrite, and marcasite; the ore averages $40 per ton.

Development consists of a tunnel driven 650 feet on the vein. The first ore shoot, 150 feet in length, was encountered 100 feet from the portal. A second ore shoot 80 feet long and 450 feet from the portal was stoped. A raise 500 feet from the portal connects with a shaft at a distance of 200 feet from the surface. Two hundred fifty feet from the portal, there is a 130-foot winze on the vein; down the winze 80 feet, a drift has been driven northeast about 80 feet; at the bottom of the winze a drift has been driven northeast 80 feet; at the face of this drift there is an underhand stope 15 feet deep and 20 feet long; here the vein is 18 inches wide. A stope 3 feet wide, 35 feet long, and 35 feet high has been worked above the underhand stope. The mill on the property consists of a Deister table, three 850-pound stamps, and plates. Capacity is 3½ tons in 8 hours. The mine is now idle.

Buckboard mine (41) embraces six claims in sec. 10, T. 30 S., R. 40 E., M.D., on the south slope of Government Peak in the Rand Mountains, 2½ miles southwest of Randsburg. The owner is Albert Ancker of Tehachapi, California.

This property, 1½ miles south of the Yellow Aster mine, is in the Rand schist, which here has been intruded by several rhyolite dikes. The principal dike is 15 to 50 feet thick. Its general strike is N. 30° W., and its dip 45° NE. The main vein, filling a fault fracture in the schist, strikes east and dips about 50° N. Hanging-wall fractures which strike north and dip east or west form junctions with the vein but apparently do not cross it. These junctions seem to have determined the locale of the ore shoot, which was mined in the upper levels. Another vein or mineralized zone occurs along the footwall of the dike. The vein filling here is largely silicified dike rock and is 6 to 7 feet wide.

The mine has been developed by three inclined shafts. The original shaft, sunk on the vein 165 feet, is now caved and inaccessible. The main shaft, 450 feet long, is sunk on a variable inclination, the bottom level being 205 feet vertically below the collar. The third shaft, 350 feet east of the main shaft, was sunk on the vein and connects at the bottom with the 250-foot level of the main shaft.

In the main shaft, levels were driven at the 100-, 150-, 250-, 350-, and 450-foot horizons. About 2,000 feet of drifts and cross-cuts have been driven. This shaft was sunk very close to the intersection of the vein and the dike, and the last 100 feet is practically in the dike. On each side of the shaft an ore shoot about 150 feet long by 3 to 6 feet wide has been stoped. These shoots occur adjacent to the intersection of the vein and dike.

Production from these workings has amounted to approximately $500,000.

The mine is idle.

Burning Moscow mine (44) comprises 12 claims in the Sageland mining district on the west slope of Piute Mountain and on the ridge south of Kelso Creek, in sec. 19, T. 28 S., R. 35 E., M.D., 3 miles west of Sageland, and 30 miles north of Mojave. It is at an elevation of 5,400 to 5,700 feet. The owner is the Piute Mining Company; W. H. White, president, and O. W. Crocket, secretary, are both of Seattle, Washington.

The vein, which occurs in granite, strikes N. 70° E., and dips 60°-70° S. The width ranges from 2 to 4 feet. Vein quartz shows free gold associated with pyrite and marcasite.

At an elevation of 5,400 feet, on a slope of the ridge above Kelso Creek, a crosscut tunnel driven 550 feet S. 30° W., intersected the vein at a depth of 250 feet below the collar of the inclined shaft, which was sunk on the vein to a depth of 150 feet; 400 feet of drifts were run on the vein from the crosscut tunnel. At an elevation of 4,900 feet on Kelso Creek a tunnel has been driven on the vein for a distance of 700 feet. Several small stopes were made on the vein on this level.

The mine is idle.

Burton, Brite, and Blank mine (45) comprises 160 acres of patented land in the NE¼NE¼ sec. 16, T. 10 N., R. 13 W., S.B., 10 miles southwest of Mojave and 12 miles northwest of Rosamond on the east slope of Middle Butte, at an elevation of 3,000 feet. The owner is the Middle Butte Mine, Incorporated, c/o Emory L. Morris, 601 First National Bank Building, Santa Ana, California.

The country rock is rhyolite, which in places is highly silicified. Near the crest of the hill is a slide, which apparently carried some of the vein down the east slope of the hill in a northerly direction for a distance of 300 to 400 feet. Some very high-grade quartz was found, all of it carrying visible free gold. The float carried from $50 to $2,000 per ton. Discovery of high-grade float on the property led to the developments on the Middle Butte, and some $10,000 was recovered from the material.

An intensive search, which included a 400-foot tunnel, a 165-foot tunnel, and a 65-foot shaft, finally resulted in the discovery of a vein 4 to 6 feet wide. This vein, trending N. 26° W., dipping 40° E., was badly broken by faulting. The displacement was in an easterly direction. Some very high-grade ore was encountered, but mineralization was irregular and spotty. No continuous ore shoot was developed. The property is now idle.

Butte mine (46) comprises 20 acres in sec. 36, T. 29 S., R. 40 E., M.D., in the east end of Randsburg; the owner is the Butte Lode Mining Company, 650 South Grand Avenue, Los Angeles, William Wegmann, superintendent.

On this property two veins 1 to 5 feet wide, in the Rand schist, are associated with a diabase dike that strikes N. 70° W. and dips 45° NE. The ore occurs along the footwall of the dike as lenses in quartz veins and as mineralized schist. In places, however, the ore cuts through the dike to the hanging-wall side.

The mine is developed by a 523-foot inclined shaft and 6,500 feet of drifts. Some $500,000 has been taken from these workings.

At present three sets of lessees are removing back fill and mining fringes of the old stopes on the 250-foot and 350-foot levels.

The ore is treated on the property in a 10-stamp mill with amalgamation plates. This mill also treats ore from the Big Dike. Total tonnage treated is about 200 per month.

Eight men are employed, including lessees.

Cactus Queen mine (48) comprises about 500 acres, including the property originally known as the Blue Eagle, in sec. 17, T. 10 N., R. 13 W., S.B., on the southwest slope of the Middle Butte at an elevation of 3,000 feet, 7 miles southwest of Mojave and 12 miles northwest of Rosamond. The owner is Cactus Mines Company, George B. Kimball, president, Roy W. Moore, manager, Pacific Mutual Building, Los Angeles, California.

The country rock is monzonite and rhyolite. The vein, which occurs at or near the contact, strikes N. 45° E., and dips 35° SE.; the width ranges from 7 to more than 15 feet. The ore contains silver and gold. The principal silver mineral is proustite. The gold is associated with pyrite, arsenopyrite, and marcasite.

Development consists of a 700-foot inclined shaft and a winze 350 feet from shaft, which extends from the 300- to 1,000-foot levels. Development on the vein is approximately 12,000 feet.

The mine equipment consists of 95-horsepower electric single drum hoist, two Ingersoll-Rand Imperial-type compressors, a completely equipped blacksmith shop, and a timber-framing shed.

Ore is hoisted in a 2-ton skip to two steel ore bins (100 tons each), then goes to a 36-inch Traylor gyratory crusher, then to a five-eighths inch vibrating screen and a 250-ton bin. Oversize is returned to the crusher. From a fine-ore bin, ore is fed by a Hardinge constant-weight feeder to a 7- by 6-foot Marcy ball mill in closed circuit with a Dorr duplex classifier, where it is ground to 85 percent minus 200 mesh. Ground ore goes to a conditioner and six Fagergren flotation cells; concentrates to an American filter, then to a drying room. Tailing goes from flotation to a cyanide plant, which consists of a 35- by 10-foot Dorr primary thickener and 35- by 20-foot four-tray Dorr thickener. Merrill-Crowe precipitation plant is used to recover the gold and silver from solution. Capacity is 125 tons per day.

Normally about 100 men are employed. The operation was shut down by War Production Board Order L-208, but recently retimbering of an exit raise has been started preparatory to some exploration work.

Chamberlain Group of Placer Claims (49A) (See also Goler Canyon Placers). The Chamberlain group comprises the following placer claims: New Dawn, Saddle, and Saddle Amended, 60 acres on the upper end of Reed Gulch in Goler mining district in sec. 11, T. 29 S., R. 39 E., M. D., 5 miles northeast of Goler siding, on the Southern Pacific Railroad and 10 miles northwest of Randsburg, at an elevation of 2,700 feet. The owner is P. C. Chamberlain, 912 South Figueroa, Los Angeles. The gold placer along Reed Gulch is 3,900 feet in length, 1,000 feet in width, and averages 12 feet in depth. The course of Reed Gulch is northwest. The average value of the gravel is reported to be 50¢ to $2.00 per cubic yard. The largest nugget, found in 1893, was valued at $1,900.

The property was subleased to the Goler Canyon Mining Company, V. E. Britton, president, J. D. Murphy, vice-president, which operated the property from 1930-34. After Britton and Murphy suspended operations, Chamberlain operated the placers from 1934-42. He located six 160-acre placer claims on Nugget Flat which is on higher ground west of Goler Gulch in secs. 33 and 34, T. 28 S., R. 39 E., M.D., 8 miles north of Goler at an elevation of 3,400 feet. Major production in the early days is reported to have been from Morman Gulch, which empties into Goler Canyon. Nuggets recovered from Nugget Flat were valued at $10 to $50 each. The bed rock underlying the gravel is sandstone. Depth of gravel is 70 feet.

These placer claims are idle.

Croesus group (57) (Little Charlie) comprises three claims on the south slope of El Paso Mountains west of Bonanza Gulch in sec. 6, T. 29 S., R. 38 E., M.D., 3 miles north of Saltdale. The owner is Jack Bishop, Trona, California. The vein, which occurs in quartz porphyry, strikes N. 40° W. and dips 75° SW.; it has a width of 1½ to 2 feet. A tunnel has been driven on the vein for a distance of 200 feet. A 40-foot winze has been sunk on the vein 150 feet from the portal. There is also a series of open cuts along the outcrop of the vein.

The ore occurs in irregular masses of iron-stained quartz.

The group is idle.

Cunningham group of placer claims (58) comprises three 20-acre placer claims in the Goler mining district at the junction of Sand Canyon and Goler Gulch in secs. 1 and 2, T. 29 S., R. 39 E., and a 160-acre placer claim in sec 27, T. 28 S., R. 39 E., M.D., 7 miles northeast of Goler siding on the Southern Pacific Railroad, 10 miles northwest of Randsburg, at an elevation of 2,600 feet. The owner is W. T. Cunningham, Wichita, Kansas.

The gravel deposit formerly worked is 1,000 feet in length and 200 feet in width. Average depth to sandstone bedrock is 7 feet. The gravel is reported to have an average value of 68¢ per cubic yard. It was worked by Britton and Murphy from 1930-34 and $1,500 in gold nuggets was reported to have been produced. Individual nuggets ranged in value from 50¢ to $400 each.

These claims are idle.

Donnie mine (64) (Copenhagen) comprises seven claims situated in the Green Mountain mining district in the Piute Mountains in sec. 6, T. 29 S., R. 34 E., M.D., 12 miles south of Weldon, at an elevation of 7,000 feet. The owner is A. M. Sargent, Weldon, California.

Four parallel veins occur in granite and are about 25 feet apart. The veins have an average width of 12 inches, and strike northeast. On Eagle Rock claim a tunnel has been driven southwest 100 feet on the Eagle Rock vein. On Jerry No. 2 claim a crosscut has been driven 120 feet to the vein. There are two tunnels on the Jerry No. 2 vein; the upper tunnel is 150 feet in length, and the lower tunnel, 100 feet below, is 150 feet in length. Two men are employed installing a 20-ton ore bin and a 20-ton ball mill.

Eureka mine (73), consisting of one claim, adjoins the Queen Esther in sec. 6, T. 10 N., R. 12 W., S.B., on the east slope of Soledad Mountain, 6 miles south of Mojave, at an elevation of 3,600 feet. The owner is the Golden Queen Mining Company.

The vein, in rhyolite, strikes N. 40° W., dips 60° NE. and ranges from 5 to 10 feet in width. It has been developed by tunnels, the lowest of which is driven 200 feet southeast on the vein.

The ore was treated in the Golden Queen mill. Production was well over $100,000.

This mine is idle.

Exposed Treasure and Desert Queen mines (74), comprising 100 acres of patented ground and 60 acres held by location, are in sec. 32, T. 11 N., R. 12 W., S.B., about 3½ miles south of Mojave on Bowers Hill, at an elevation of 2,900 feet. The owner is Gordon Gray, San Diego, California. Mines are under lease and bond to Standard Hill Mines Company, John Rosecrans, president, E. B. Blickenstaff, general manager, Mojave, California.

Seven parallel veins have been developed on the property; the Exposed Treasure and Desert Queen have been the most productive. These veins occur in rhyolite which is in contact with monzonite on the west. In general the strike of the veins is north, but numerous branches trend N. 30° W. The dip near the surface is about 60° NE., but flattens to 25° 900 feet down the vein. The veins are 4 to 15 feet wide.

A 900-foot shaft has been sunk on the Exposed Treasure vein, with levels at intervals of 100 feet. There are more than 10,000 feet of drifts, crosscuts, and raises. On the Desert Queen vein a shaft has been sunk 400 feet with levels at 100, 200, 300, and 380 feet. A crosscut driven 900 feet west on the 380-foot level of the Desert Queen shaft encountered the Exposed Treasure vein. A heavy flow of water here proved too expensive to handle.

Present operators have sunk a 130-foot shaft on the Revenue vein. This shaft is about 600 feet southeast of the Exposed Treasure shaft. At the bottom of the Revenue shaft, a drift driven south for 60 feet encountered a fault striking S. 40° E.; for the next hundred feet the drift was in the fault zone. It will now be turned east to pick up the faulted segment. On the Yellow Rover a tunnel has been driven 600 feet N. 55° W., and at the face a 150-foot winze has been sunk with levels at 75 and 150 feet. There are 250 feet of drifts on the 75-foot level and 300 feet on the 150-foot level. This ground was stoped for a width of 3½ feet. Production from the property has exceeded $2,000,000.

Five men are working.

French Meadows Mine (37, 109) (See Bowman).

Gold Bar Placer mine (81) comprises three 20-acre placer claims on the Kern River in sec. 33, T. 27 S., R. 31 E., M.D., 2½ miles northeast of Democrat Hot Springs, at an elevation of 2,300 feet. The owner is Mrs. Elisabeth J. Hercig, Los Angeles, California.

The property is under lease to Dan Magnesson and Associates, Los Angeles. The gravel, which occurs in the Kern River, is 8 to 10 feet in thickness, about 500 feet in length, and 200 feet in width. Dragline equipment, trommel, sluices, jigs, and concentrator are being installed. Four men are employed.

Gold Cross and Standard groups (83) (Eclipse, Edith, Paris, Standard), consisting of six claims, are in secs. 21 and 28, T. 30 S., R. 33 E., M.D., on Indian Creek, just south of Caliente Creek, about 12 miles east of Caliente, at an elevation of 3,000 to 4,000 feet. The owner is Clarence G. Talleur, Carson City, Nevada; property is leased to Mineral By-Products, Limited, W. R. Palmer, North Hollywood, Fred A. Bennett, Hollywood, and John T. Davis, Burbank, California.

The Gold Cross vein strikes east and dips 45° S.; the walls are quartz porphyry, the filling is largely quartz; the width is as much as 18 feet. The vein, where now exposed, may average 14 feet in width. The valuable minerals are pyrite and silver sulphides.

Development consists of a shaft 117 feet on the vein; a tunnel at the collar of the shaft, driven east 200 feet; and two short tunnels in the hill above. At the portal of the lowest tunnel the vein has a width of 14 feet and is well mineralized.

The Standard vein is 400 feet south of the Gold Cross and roughly parallel to it. The strike is east, the dip 60° N.; the vein filling is quartz and decomposed wall rock. The walls are quartz porphyry. The width is about 10 feet. The valuable minerals are largely silver sulphides.

Development includes a tunnel driven S. 55° W. 100 feet to the vein, then 360 feet west on the vein. Material in the drift is presumably ore. About 300 feet above is tunnel No. 2, driven west 300 feet on the vein.

The lessee has cleaned out the lower tunnel and repaired the road, preparatory to shipping ore to a leaching plant at Saugus, California. Construction of this plant is to start immediately.

Gold Peak (89) (Zada), consisting of 240 acres, patented, is in secs. 28 and 29, T. 30 S., R. 33 E., M.D., south of Caliente Creek on the ridge between Indian Creek and Studhorse Creek, 11 miles east of Caliente, between 3,000 and 4,000 feet elevations. The owner is Clarence G. Talleur, Carson City, Nevada. A lease is held by Basic Metals, Limited, Ray C. Stoner, Charles H. Kidder, and H. V. Burgard, general partners, 2453 North Beachwood, Los Angeles.

This property was developed and operated in the early years of the twentieth century (about 1903-07). During this period 110 cars of ore were shipped. The ore averaged $89 per ton. Ore was also treated in a 20-stamp mill on Studhorse Creek. The mill was destroyed by fire some years ago. Total production is not known.

Most of the country rock is granodiorite, but the walls of the vein are quartz porphyry. There are several veins on the property, but only one, the Zada, has been worked. The strike of this vein is nearly east; the dip ranges from 45° S. near the surface to almost 80° S. in the lower tunnel. The width is about 10 feet, although the early-day miners took only an average of 3½ feet on the hanging-wall side. The vein filling is quartz and altered wall rock. The valuable minerals are pyrite and silver sulphides. Silver constitutes 95 percent of the valuable constituents.

The Zada was developed by three tunnels. The lowest one, No. 3, is at an elevation of approximately 3,250 feet, 725 feet below the outcrop. It was driven N. 11° 59′ E. 525 feet to the vein. A drift 80 feet west connects with old workings made from an earlier No. 3 tunnel. Tunnel No. 2 is 200 feet above No. 3 and is driven eastward 500 feet; it connects with tunnel No. 1 by four raises. Four ore shoots aggregating some 400 feet in length were stoped from these tunnels for an average width of about 3½ feet.

Present operators have cleared tunnel No. 3 and built a bin at its portal. Equipment consists of a 210 cubic foot Worthington compressor. About 1½ miles of road has been built to the Gold Peak and the adjoining Old Cowboy, which is held by the same lessee.

The metals are to be extracted by a newly developed leaching process at a mill under construction at Saugus.

Gold Standard mine (91) comprising three claims, is in sec. 12, T. 28 S., R. 33 E., M. D., in the Green Mountain mining district about 5 miles east of the Bright Star mine and 12 miles southeast of Bodfish. The elevation is 5,800 feet. The owners are J. E. Moreland, Bodfish, California, and the Mrs. J. H. Potter estate, Porterville, California.

Two parallel veins about 100 feet apart, which cut the slate country rock, strike N. 70° E., and dip 50° SE. They are 8 inches to 2 feet wide, and average 12 inches.

Development is by tunnel driven northeast 150 feet with a 30-foot winze 100 feet from the portal. The ore shoot above this winze is 40 feet long, about 18 inches wide, and is said to average $70 per ton. There is a 30-foot tunnel on the other vein which is 100 feet south of the main workings.

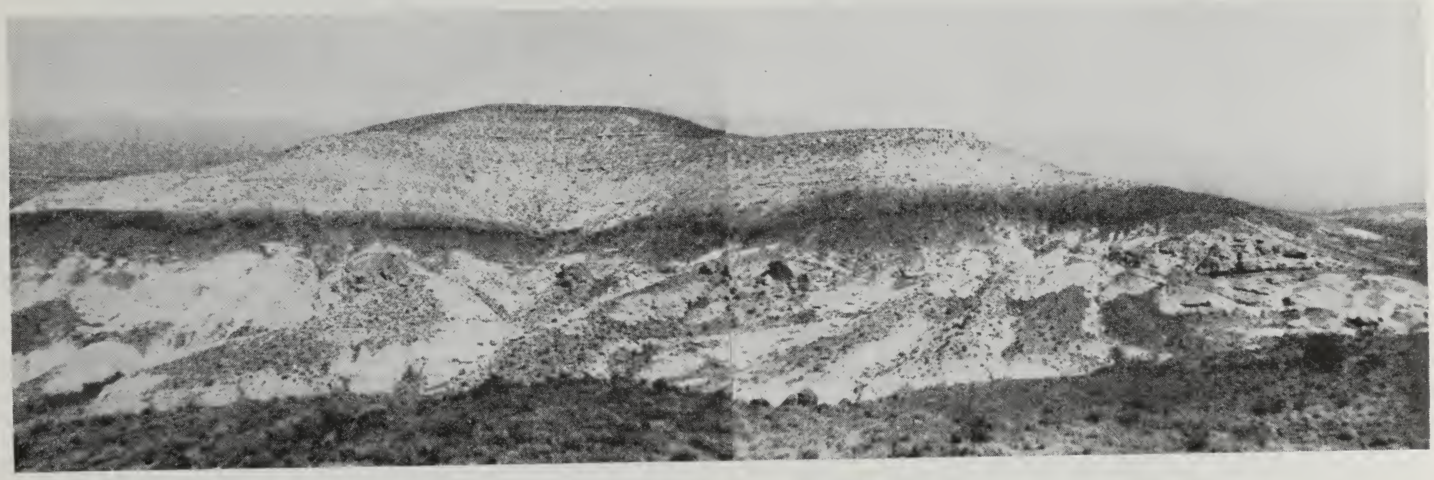
The mine is idle.

Golden Queen Mining Company (92)[5], W. C. Browning, vice-president and general manager, and Edwin H. Oshier, mine superintendent, 1211 Pacific Mutual Building, Los Angeles, own or control the following properties on Soledad Mountain in the Mojave mining district about 4½ miles south of Mojave: Queen Esther, Golden Queen (Silver Queen), Lodestar (Starlight), and Soledad Extension. These properties, aggregating about 600 acres, are in secs. 6 and 7, T. 10 N., R. 12 W., S. B.

Since the company took over the Silver Queen mine (now known as the Golden Queen) in 1935, four principal veins have been developed and worked on the various properties in addition to two footwall branches of the Silver Queen vein. The principal veins, the Silver Queen, the

---

[5] Julihn, C. E., and Horton, F. W., The Golden Queen and other mines of the Mojave district, California: U. S. Bur. Mines Inf. Circ. 6931, 42 pp., 1937.

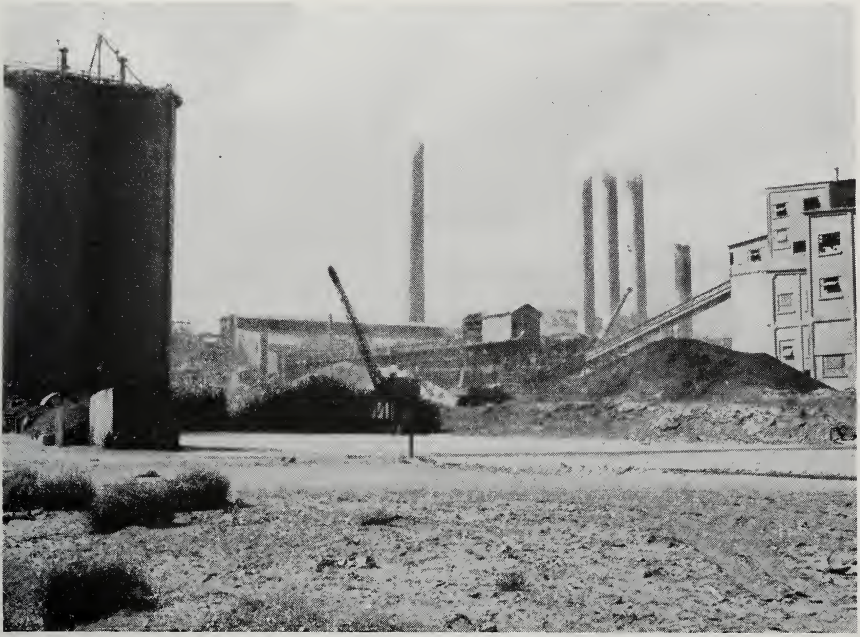


OPAL PUMICE DEPOSIT, EL PASO MOUNTAINS

A, Mining gypsum.

B, Hauling gypsum. Loader in background.

H. M. HOLLOWAY, INC.
Photos by C. V. Averill

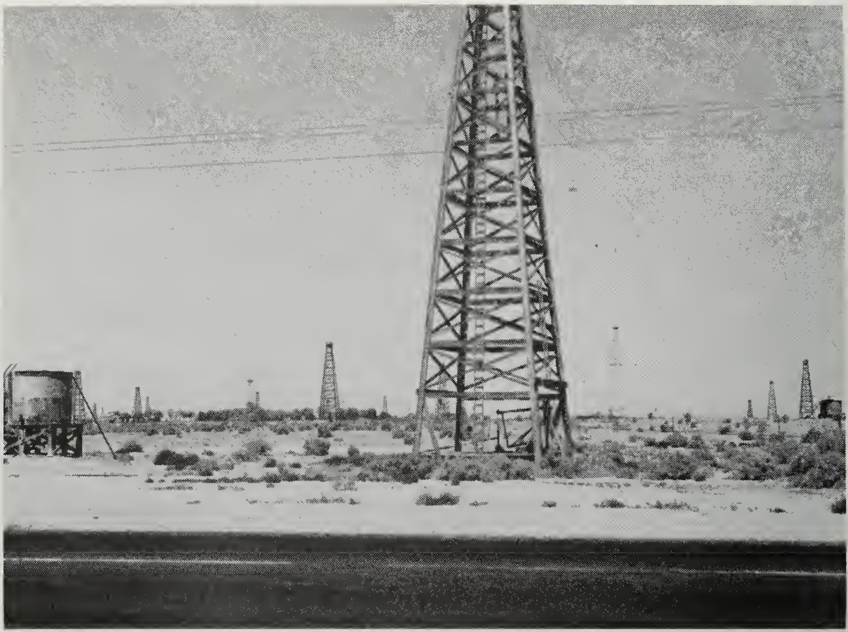


A, Cement plant.

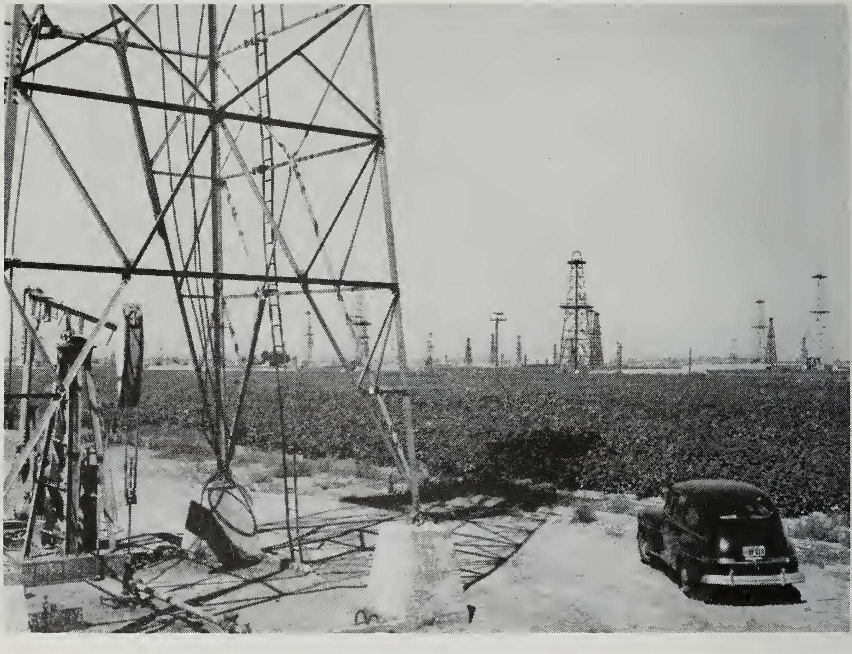
B, Quarry. Narrow-gage locomotive in center.

MONOLITH PORTLAND CEMENT COMPANY

Photos by C. V. Averill



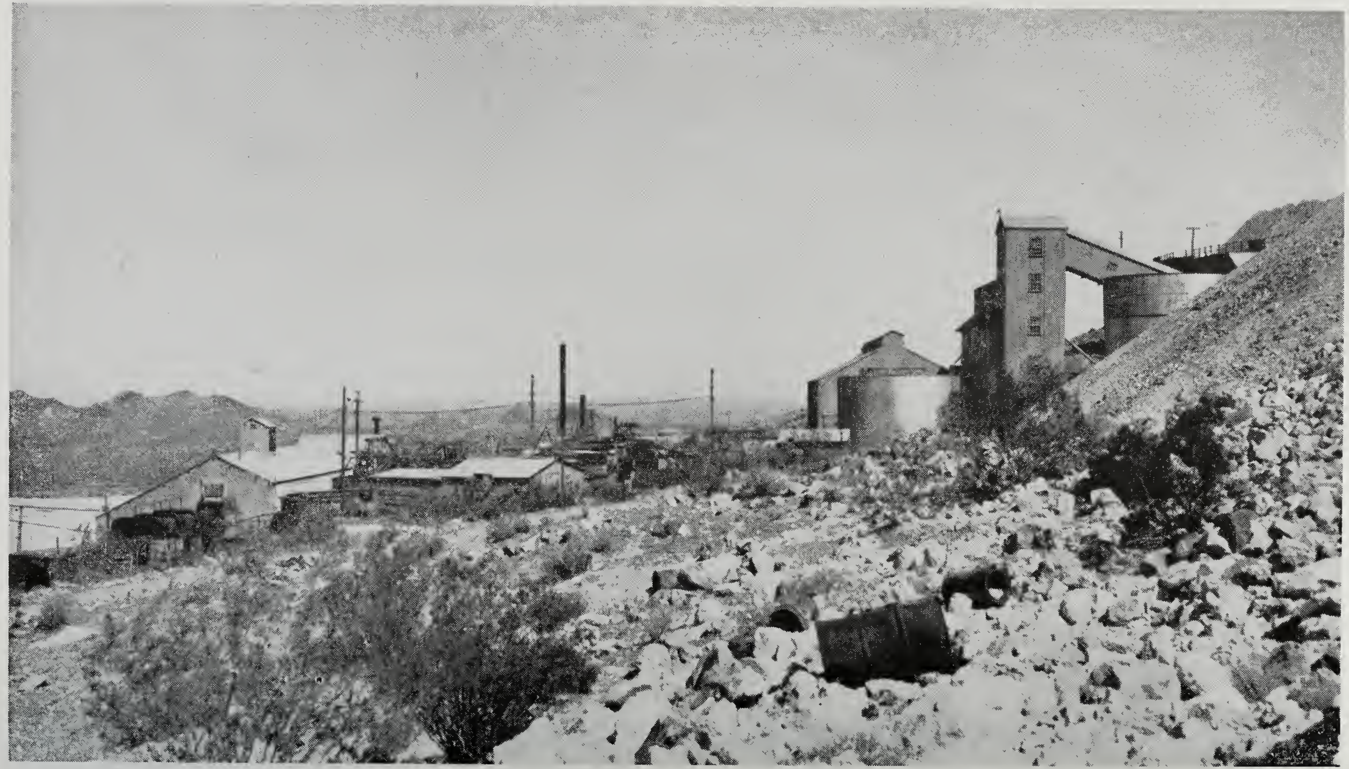
A, LOST HILLS OIL FIELD
Photo by C. V. Averill



B, EDISON OIL FIELD
Photo by C. V. Averill

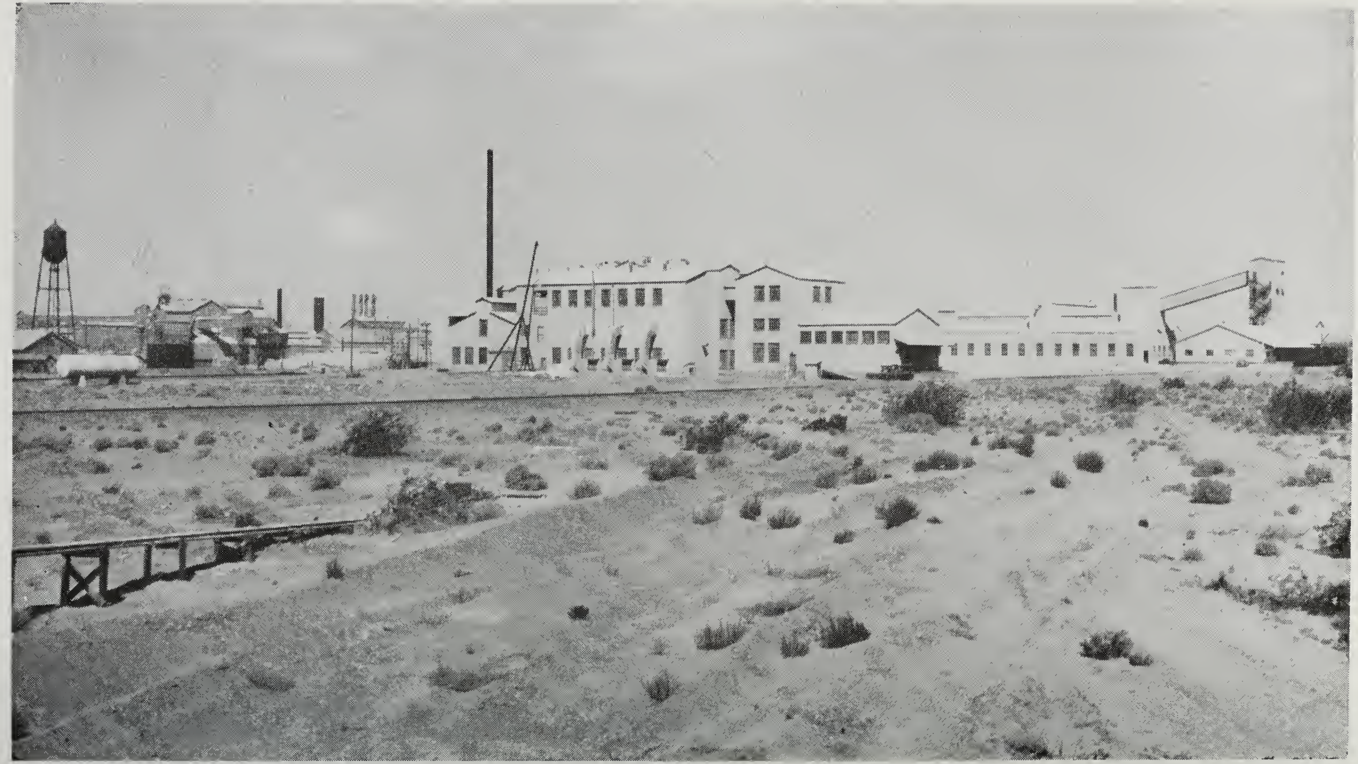
A, CUDAHY VOLCANIC ASH DEPOSIT, LAST CHANCE CANYON

B, HIGH PEAK TUNGSTEN MILL



GOLDEN QUEEN MINE
Photo by C. V. Averill

LONG BEACH SALT COMPANY
Photo by C. V. Averill



PACIFIC COAST BORAX COMPANY
Photo by C. V. Averill

Golden Queen, the Lodestar, and Soledad Extension, are roughly parallel with a general strike of N. 40° W., but the Silver Queen dips about 55° NE. whereas all of the others dip southwest. The two footwall branches of the Silver Queen strike N. 20° W. and dip about 70° NE.

These veins occupy fault fractures in rhyolite flows. Three types of flows have been encountered. These are known locally as felsitic, fragmental, and porphyritic. The felsitic flow is believed to have had the greatest influence on mineral deposition.

The Silver Queen vein fills a fault fracture along the contact of separate rhyolite flows. It has an average stoping width of 10 to 30 feet, although locally it may be as much as 50 feet in width. The vein filling is brecciated quartz and silicified wall rock. The gold occurs free, in a very finely divided state; the silver occurs as cerargyrite and argentite. Approximately 60 percent of values are in gold, 40 percent in silver. This vein is developed by three adits, the 200-, 400-, and 600-foot levels. The greatest length of development is 1,700 feet on the 200-foot level. The 600-foot adit at an elevation of 3,155 feet is 8 by 8 feet in section and is the main haulage way for all of the mines. It has a total length of 4,600 feet. Driven in a southeasterly direction, it connects with ore passes from each of the levels in the various mines. Fifteen hundred feet from the portal it intersects the supply shaft from the 200-foot adit (this was formerly known as the Kenneth Holmes winze). At a point 600 feet southeast of this intersection it was driven southwest 1,200 feet to connect with the 600-foot level of the Lodestar mine, thence south 400 feet to connect with the 600-foot level of the Soledad Extension, thence generally southeast 900 feet to a winze. This winze has 200 feet of development on the 700-foot level; and 2,400 feet of workings on the 800-foot level, which connect with the Soledad Extension.

Nos. 1 and 2 footwall veins strike N. 20° W. and dip 70° NE. For a length of 500 feet, they have been stoped above the 300-foot level to their junctions with the Silver Queen vein.

The Golden Queen vein, approximately 300 feet west of the Silver Queen, strikes N. 40° W. and dips 70° SW. It has been developed 1,800 feet along its strike and stoped part of the way to the surface. All of this development work is on or above the 200-foot level of the Silver Queen, which level is 400 feet below the surface. Its average stoping width is 15 feet.

The Lodestar vein (Starlight) is 200 feet southwest of the Golden Queen. Its general strike is northwest, its dip 70° SW., and its width 8 to 20 feet, averaging about 13 feet. The vein filling is highly brecciated, consisting of quartz and iron-stained altered rhyolite. The valuable constituents are gold and silver. The gold occurs free; silver, as cerargyrite. The ratio of silver to gold is approximately 20 to 1 by weight. The ore shoot developed ranges from 800 to 950 feet in length.

The mine is developed on four levels: No. 1, an adit at an elevation of 3,638 feet, was driven southeast 800 feet on the Lodestar (Starlight) vein.

No. 2, an adit at an elevation of 3,538 feet, was driven east 200 feet to the Gray Eagle vein, then about 2,800 feet southeast. Approximately 2,000 feet from portal, an ore shoot 900 feet in length and 13 feet in width was encountered. At 2,100 feet from the portal, a winze in the hanging wall of the vein was sunk 250 feet.

No. 3, an adit at an elevation of 3,355 feet, was driven southeast 2,500 feet. The last 950 feet was in ore.

No. 4, at an elevation of 3,170 feet, about 1,500 feet in length, was developed through winzes. It connects with the main haulage level (600-foot) of the Golden Queen mine, through which ore from this mine goes to the Queen mill.

Soledad Extension vein is 500 feet southwest of Lodestar vein. Its strike is N. 40° W., its dip 53° SW. It is in a fault fissure at or near the contact of rhyolite and rhyolite porphyry. The average width is 15 feet; the vein filling, consisting of quartz and altered iron-stained wall rock, is highly brecciated. The ore contains free gold. Silver is in the form of cerargyrite and argentite. Two ore shoots have been developed, one 120 feet in length, the other 140 feet in length; each averages 15 feet in width. These shoots are separated by 100 feet of low-grade vein material.

The Soledad Extension is developed by an adit driven southeast 1,200 feet, which is connected by a raise to the Golden Queen 200- and 100-foot levels. Four hundred feet from portal, there is a 600-foot winze. A level in the winze 200 feet below the adit, connects with the 600-foot level (haulage level) of the Golden Queen mine. Four hundred feet below the adit (800-foot level), a drift has been driven 1,400 feet southeast to a winze sunk from the southeast end of the Golden Queen mine haulage level, thence 1,000 feet southeast.

In addition to the above-described development there are numerous crosscuts, raises, and parallel drifts which bring the total to several miles of connecting underground workings.

Three systems of mining are used [6]: shrinkage stope, square set, and a combination of square set and cut and fill called ''square-set slot and pillar system.'' Where the back stands well, which is usually where the ore is 20 feet or less in width, shrinkage stopes are worked. If the ground is dangerous, straight square setting is used. Where the ore is wide and backs may be heavy, the modified method is used. In brief, this method may be described as follows:

On 25- to 50-foot centers (depending upon condition of the pillars) ''slot'' stopes, one or two sets wide (length of stope being from footwall to hanging wall) are mined, with lagged square sets. Pillars between slots are then mined by square set or cut and fill, depending upon character of the ground. Glory holes furnish fill material through raises. This waste is delivered to and distributed in the stopes by air-operated slushers, which are also used to drag the broken ore on the floor of the stope to the nearest chute. The ore is broken onto timber mat laid on successive layers of fill. If square sets are used, they are placed on a double floor of crossed boards on top of fill.

The ore is hauled in trams of twelve 2-ton cars which are pulled by storage-battery locomotives, to the 400-ton cyanide plant near the portal of the haulage level.

Since the last descriptions of this plant were published [7], a cyanide recovery plant has been installed. Sulphur gases are mixed with barren solution in wooden drums. The hydrocyanic acid released is conducted through a closed container to other wooden drums where it is mixed with solution and lime. The calcium cyanide solution thus formed is returned to the mill circuit. The decyanided solution is sent to the filter.

---

[6] Kumke, Charles A., Slot system of mining at Golden Queen mine, Mojave, California: Am. Inst. Min. Met. Eng. Trans., vol. 126, pp. 27-32, 1937.

[7] Tucker, W. B., Mining activity at Soledad Mountain and Middle Buttes, Mojave mining district, Kern County: California Div. Mines Rept. 31, pp. 477-479, 1935.

Tucker, W. B., and Sampson, R. J., Current mining activity in southern California: California Div. Mines Rept. 36, p. 31, 1940.

The mines were shut down following the War Production Board's Order L-208 and operations have not yet been resumed (August 1946).

Goler Canyon Placers (93) (49A, 114) (See also Chamberlain and Janney Placers). The Goler Canyon deposits are situated on the south slope of El Paso Mountains. The mountains are cut through in places by washes and gulches which empty southward into the sink of Desert Springs Valley. On the north side of the mountains is a series of beds of conglomerate, sandstone, volcanic tuff, and lava flows, dipping away from the range at an angle of 25°. The conglomerates at the base are free from volcanic pebbles, and consist of many kinds of rocks, some of which are foreign to the district. These are quite firmly cemented, and are overlain by standstone and volcanic beds. This is evidently a marginal-sea or lake-bottom deposit which has been elevated from the south and tilted northward. Jawbone, Red Rock, and Goler Canyons, and lesser tributary canyons emptying southward, have cut these beds to a great depth. It is in these canyons and on the hills bordering them that most of the placer gold is found. In Goler Canyon as in other gulches, the gold occurs in the wash from the basal conglomerates and tuffs. The Benson and Reed Gulches, which were the first discovered (1893) that contained big nuggets, empty into Goler Canyon at its junction with the desert plain. It is reported that nuggets found in Benson and Reed Gulches ranged in value from $10 to $50 apiece. The sparse distribution of the gold in the conglomerates, and its more abundant distribution in the gulches cutting them, indicate it was derived from the conglomerate.

Greenhorn Caves Placer Mines (99) comprises three 160-acre placer claims on the east slope of the Greenhorn Mountains, and on a ridge east of the Kern River in sec. 19, T. 27 S., R. 32 E., and in secs. 12, 13, and 24, T. 27 S., R. 31 E., M.D., 13 miles southwest of Isabella, at an elevation of 3,400 feet. The owner is the H. P. Bardshaw estate, Los Angeles.

A fault in the granites can be traced for several miles. This fault is in the form of an open crevice, and it cuts a channel at a higher elevation on the Greenhorn Mountains. This channel strikes east and is 500 feet in width. The channel is filled with quartz gravel. A steady flow of water during the winter months deposits the gravel in the fault fissure, and also concentrates the gold along benches in the fissure. At an elevation of 3,325 feet, a tunnel has been driven 188 feet west to the fault, then 72 feet northwest along the fault. This tunnel is approximately 450 feet below the shaft workings. At an elevation of 3,750 feet, a shaft has been sunk on the fault fissure to a depth of 100 feet. At the bottom of the shaft there is a drift along the fault 100 feet southeast and 75 feet northwest. The benches in the fault where gravel is deposited have been cleaned up at various times, and the production is reported to have been $60,000.

The mine is now idle.

Gwynne Mine (102, 117) (Jennette). The Gwynne property comprises 445 acres of patented mining claims in the Green Mountain mining district on the west slope of the Piute Mountains in secs. 21 and 22, T. 29 S., R. 34 E., M.D., 25 miles northwest of Mojave, at an elevation of 7,500 feet. Owners are Otto and Jack Geringer, of Mojave, California.

The following mines are on the property: Gwynne, Jennette, Dearborne, and Mace. The principal production has been from the Gwynne and Jennette mines. Three nearly parallel veins which occur in granite are known as the Gwynne, Jennette, and Kersey veins. The Gwynne and Jennette veins strike east and dip 40° S. They range in width from 6 inches to 2 feet. The Kersey vein strikes N. 35° E. and dips 40° S.; its width is 4 to 6 feet. The vein quartz from Gwynne and the Jennette shows free gold associated with pyrite, arsenopyrite, and scheelite. Usually it is freemilling high-grade ore. The average value of the milled ore runs $40 per ton. The mined ore from the Kersey vein is reported to have an average value of $20 per ton.

The Gwynne is developed by a shaft sunk 300 feet on the vein and by two tunnels driven east on the vein. The upper tunnel is 900 feet in length. The main working tunnel, 100 feet lower in elevation, is 2,600 feet in length. At a distance of 1,600 feet from the portal of the second tunnel, a raise extends along the vein to the surface. At 2,000 feet there is also a 300-foot raise. The Kersey vein, which is southeast of the Gwynne vein, is developed by a tunnel driven 600 feet north, a winze 85 feet deep, and a drift north from the winze on the vein about 200 feet. The ore shoot developed on this vein was 150 feet in length and averaged 4 feet in width.

The Jennette vein is developed by a crosscut tunnel driven 150 feet south to the vein, with a drift on the vein 700 feet west. Two ore shoots were developed 300 feet in length in these workings. The vein has an average width of 6 inches. It is free-milling, high-grade ore. The milled ore is reported to average $50 per ton in gold. Since 1933, all mining has been confined to the Gwynne vein, and the ore treated is reported to have averaged $40 per ton in gold. After Limitation Order L-208 of the War Production Board closed gold mines, the owners confined their attention to the recovery of scheelite, which occurs in irregular masses in the Gwynne vein. Some small shipments of concentrates were made. The ore is trammed from the lower Gwynne tunnel to the mill, which has a capacity of 25 tons. Ore from the 25-ton bin goes to a Blake-type crusher, then to a 4- by 4-foot ball mill. Product from the ball mill is elevated by bucket elevator to a Cottrell vibrating screen, and screened to minus 30 mesh; oversize is returned to the ball mill, and minus 30 mesh goes to the Senn amalgamator; pulp from the amalgamator goes to the Wilfley concentrator. The property has a total recorded production of $770,000. Three men are employed on development work.

Hanover mine (104) comprises two claims and two fractions in secs. 21 and 22, T. 29 S., R. 34 E., M.D., adjoining the Gwynne mine on the north, in the Green Mountain mining district in the Piute Mountains, 25 miles northwest of Mojave. The vein occurs in granite, strikes N. 70° E., dips 40° SE., and is 12 inches to 2 feet in width; elevation of the deposit is 7,500 feet. The owner is Piute Mines, Limited, J. W. Steele, agent, Los Angeles, California.

Development consists of two tunnels. The upper tunnel is driven 150 feet on the vein and stoped 100 feet toward the surface. About 140 feet below the upper tunnel, the lower tunnel is driven as a crosscut 300 feet south to the vein, with drifts 600 feet northeast and 100 feet southwest. A mill having a capacity of 20 tons has been installed below the lower tunnel.

The mine is now idle.

Hub group of claims (106) comprises four claims, the Hub, Hub No. 1, Hub No. 2, and Hub No. 3, situated on the ridge between Jawbone and Trail Canyons in sec. 4, T. 31 S., R. 35 E., M.D., 4 miles south of Weldon's ranch and 16 miles north of Mojave. The elevation is 5,500 feet. The owners are D. R. Little, Glendale, California, and Fred Hockett, Lancaster, California. A quartz vein occurs in rhyolite, strikes N. 10° E., dips 70° E., and has a width of 2 feet. It is developed by a 10-foot shaft and shallow trenches.

Five tons of ore, mined and shipped to Burton Brothers at Tropico Mines, averaged $32 per ton. Two men are employed.

Iron Hat group of six claims (113) is in sec. 1, T. 29 S., R. 39 E., M. D. in El Paso Mountains 12 miles northeast of Randsburg and three miles north of Garlock. The owner is William Schmidt, Johannesburg, California. The group was under lease to Jerry Quigley of Bakersfield, California, from 1935-38.

The lessee sank a vertical shaft 500 feet and crosscut south at the bottom. No further information is available.

The mine is now idle.

Janney group of placer mines (114) (see also Goler Canyon placers), comprises seventy 160-acre placer claims, in the Goler mining district and Summit Diggings mining district. The claims located in the Goler district are 7 miles northwest of Randsburg, in secs. 2, 3, 10, 11, 23, 24, 25, 26, T. 29 S., R. 39 E., and secs. 4, 5, 8, 9, 10, 17, 18, 19, 20, 21, 30, T. 29 S., R. 40 E., M. D. The elevation is 2,500 to 3,400 feet. The owner is John Janney, Pioche, Nevada; the superintendent, S. M. Mingus, Randsburg, California.

The principal operations were on Benson Gulch, and the gravel along this gulch has been worked for a distance of 1½ miles. The depth of gravel is 6 to 15 feet. Operation was intermittent from 1934-41. The gravel is reported to run from 50¢ to $2.00 per cubic yard, and some of the nuggets found were valued from $10 to $50. The equipment consists of two steam shovels. Water was secured from the Janney well at an elevation of 2,100 feet. The depth of well is 600 feet.

The mine is now idle.

Jennette-Grant Mines (116). The property comprises 24 claims, in the Green Mountain mining district in the Piute Mountains, on a ridge east of Erskine Creek in secs. 4 and 10, T. 28 S., R. 34 E., M. D., 15 miles south of Weldon. The elevation is 5,500 to 6,000 feet. The owner is Jennette-Grant Mining Company, George Bergner, president, Harrisburg, Pennsylvania; N. C. Anderson, of Bodfish, California, is manager.

A series of parallel veins, in schist near the contact with limestone, strike northeast and dip 60° N. On the Grant group of claims east of the Bright Star mine, a shaft has been sunk 125 feet on a vein that strikes northeast, and dips 60° N. The width is 12 inches to 2 feet. The principal development is on the Jennette group of claims in the canyon east of Erskine Creek. At an elevation of 5,500 feet, a 550-foot crosscut tunnel was driven S. 70° E. in limestone. From it, a drift was run 350 feet northeast in schist. One hundred feet from the portal, the drift intersected the Mayflower vein. The vein occupies a fissure in the limestone, strikes N. 30° W. and has a width of 4 feet. It is reported to average $6.00 per ton in gold. In fractures in the limestone, some lenses of sphalerite occur. The schist is mineralized with pyrite, arsenopyrite, and sphalerite, which are reported to carry gold. Schist samples cut in the tunnel for a distance of 350 feet are reported to have an average value of $3.50 per ton in gold.

Mine equipment consists of a 8- by 8-inch Rix compressor, air drills, a blacksmith shop equipped with forge and drill sharpener, and a cyanide leaching plant with a capacity of 40 tons per 24 hours. The plant was used for treatment of the Bright Star mine tailings. About 800 tons of tailings were put through in 1942. On the ridge north of the crosscut tunnel, a vein containing stibnite occurs along a contact of limestone and slate. A tunnel was driven 70 feet along the contact, to develop a short lens of ore. In 1918 a shipment of antimony ore valued at $13,000 was made from these workings.

The mine is now idle.

Joe Walker mine (118) comprises two patented claims in sec. 7, T. 29 S., R. 33 E., and sec. 12, T. 29 S., R. 32 E., M.D., in the low foothills at the northeast edge of Walkers Basin, 7 miles northwest of Piute. The owners are the J. B. Haggin and Phoebe A. Hearst Estates. It is leased to Dan Cronin and associates of Bakersfield.

This mine was discovered in 1865 and operated until 1874. The production was $500,000 to $600,000.

Lessees are pumping out the workings through the 350-foot shaft. As of November 1, 1946, they were within a few feet of the 250-foot level.

Equipment consists of a D.C. 17,000 caterpillar engine driving a 100 kilovolt-ampere generator (tex rope drive), 3- by 4-inch and 4- by 5-inch Fairbanks-Morse pumps, pumping 800 gallons per minute, 400 gallons of which is water constantly coming into the mine from outside sources.

Four men are employed.

Josephine mine (119), comprises two claims, the Josephine No. 1 and No. 2, in the Clear Creek mining district in the Piute Mountains, in sec. 34, T. 27 S., R. 33 E., M.D., 8 miles southeast of Bodfish. The elevation is 5,000 feet. The owner is Tom Smith of Bodfish, California.

A quartz vein which occurs in granite, strikes N. 10° W., dips 40° E., and has a width of 6 to 18 inches. On Josephine No. 2 claim, a tunnel has been driven 25 feet south on the vein. On Josephine No. 1 claim a crosscut has been driven to the vein, with a drift 70 feet south on the vein and a stope to the surface. The mine is reported to have produced some high-grade ore.

The mine is now idle.

Jumbo group of mines (122) comprises three lode claims, the Jumbo No. 1, Jumbo No. 2, and Jumbo No. 3, situated in the Goler mining district in sec. 2, T. 29 S., R. 39 E., M.D., 1 mile northeast of the Yellow Aster Mining Company's pumping station, and 3½ miles north of Goler. The elevation is 2,500 feet. The owner is P. C. Chamberlain, 912 South Figueroa Street, Los Angeles, California.

A rhyolite porphyry dike striking N. 50° W. and dipping 45° NE., occurs on these claims. The dike, 75 to 100 feet in width, has a schist hanging wall, and a diorite footwall. Development consists of two shafts, the No. 1 shaft, 26 feet deep, and No. 2 shaft, about 350 feet to the southeast. The No. 2 shaft is 75 feet deep and is on the Jumbo No. 2 claim.

At a depth of 50 feet the rhyolite was mineralized with pyrite. Samples assayed $1.68 per ton in gold. The width of the mineralized rhyolite was 2 feet. Below 50 feet, the rhyolite was not mineralized.

The mine is now idle.

Karma mine (123) comprises the Karma, Ajax, and Intention Junction claims, in sec. 6, T. 10 N., R. 12 W., S.B., on Soledad Mountain, about 4 miles south of Mojave. The elevation is 3,200 feet. The owner is E. L. Wegmann, Mojave, California.

The 20-stamp mill on this property was recently destroyed by fire. The mine is now idle.

King Solomon mine (126) comprises five patented claims in sec. 35, T. 29 S., R. 40 E., M.D., in the Rand mining district, three-quarters of a mile west of Johannesburg, at an elevation of 3,900 feet. The owner is Shipsey Mining Company, Albin Walton, president, 600 Mound Avenue, South Pasadena, California. The property was leased to Atkinson, Gates, and Cavalli, Red Mountain, California. The mill is leased to Max Hess of Johannesburg, California.

Four veins have been explored on this property. The country rocks are schist and quartz monzonite. In places, either of these rocks may form both walls of a vein, or one may be the foot and the other the hanging wall. Usually the walls are well defined, as they show slickensides and are separated from the vein material by gouge.

The veins are known as the Blind, Nosser, Magpie, and King Solomon. The strikes range from N. 35° W. to N. 80° E., and the dips range from 40° to 50° NE. They are generally narrow. The actual pay ore averages less than 2 feet.

Principal development consists of a 45° inclined shaft sunk 700 feet, with seven levels and approximately 11,500 feet of lateral workings.

The present lessee has raised from the 450-foot level to the 300-foot level, for ventilation. This raise is about 250 feet south of the shaft. Some diamond drilling has been done from underground points.

The mill has been operating on ores from various dumps in the district and will treat the ore from the mine when underground operations are started.

Ladd mine (129) comprises 640 acres on a small butte of rhyolite, in sec. 36, T. 11 N., R. 12 W., S.B., 5 miles southwest of Mojave, at an elevation of 2,840 feet. The owner is O. H. Ladd, Mojave, California.

In an open cut on the northeast slope of the butte is a series of small fractures which strike northeast in the rhyolite. These fractures are 6 to 8 inches wide. Samples cut are reported to carry $3.00 per ton in gold. On the south slope of the butte, a trench 100 feet long by 6 feet deep cuts the rhyolite, which strikes east, and dips 60° N. In the north end of this trench is a 4-foot vein of brecciated quartz. Samples cut across the 4 feet are reported to assay $3.00 per ton in gold. There are also a number of trenches east of the main trench, which are 10 feet apart for a distance of a quarter of a mile. On a parallel quartz vein 4 feet in width, which strikes east and dips 80° N., a shaft has been sunk 35 feet, and at the bottom of the shaft a crosscut has been driven 25 feet north. Samples taken from vein are reported to carry $4.00 per ton in gold.

The mine is now idle.

Locarno mine (gold-tungsten) (138) comprises 97 acres of patented land in the Green Mountain mining district on the southwest slope of the Piute Mountains in the SE¼ sec. 21, T. 29 S., R. 34 E., M.D., 25 miles northeast of Caliente. The property adjoins the Gwynne mine on the southwest. The elevation is 7,000 feet. The owner is N. V. Franceshi, Los Angeles.

A series of parallel quartz veins occurs in the granite. The north vein strikes N. 30° E., dips 40° SE., and ranges in width from 12 inches to 2 feet. About 20 feet south of this vein is another quartz vein with the same general strike and dip.

A 500-foot tunnel has been driven N. 30° E. on the north vein. A raise 230 feet from the portal extends 110 feet to the surface on the vein. A 35-foot winze is 35 feet from the portal. A lower tunnel is driven 550 feet on the vein 130 feet below the upper tunnel. The vein developed in this tunnel ranges in width from 12 inches to 2 feet. A winze on the vein, 410 feet from the portal of the lower tunnel, has a depth of 93 feet. The ore mined is reported to average $15 in gold. Scheelite occurs in an irregular manner in the vein. In the lower tunnel, free gold is associated with pyrite.

Equipment consists of a Hallet and Hallet compressor, capacity 120 cubic feet, driven by 15-horsepower Fairbanks-Morse gas engine. The mill has a 25-ton ore bin, a 6- by 8-inch Blake crusher, and a Gibson ball mill driven by a 15-horsepower Fairbanks-Morse gas engine.

Two men are employed.

Lone Star mine (139) comprises nine claims in secs. 7 and 8, T. 28 S., R. 34 E., M.D., 11 miles south of Weldon, in the Green Mountain mining district on the north slope of the Piute Mountains, adjoining the Bright Star mine and the Grant mine on the east. The elevation is 7,500 feet. The owner is the Lone Star Mining Company, J. E. Moreland, president and manager, Bodfish, California.

A series of parallel northeast-trending veins occurs in schist and slates. The principal development has been on the Lone vein, which strikes N. 70° E., and intersects a vein that strikes N. 45° E. and dips 40° SE. The width of the vein ranges from 3 to 6 feet, the average width being approximately 3 feet. The vein is reported to have an average value of $25 per ton in gold. A shaft has been sunk on an inclination of 45° a distance of 100 feet; on the 50-foot level is a drift on the vein 200 feet southeast and 70 feet northeast. The vein on the 100-foot level strikes N. 45° E., dips 40° SE., and has an average width of 3 feet. Two ore shoots were developed southwest of the shaft. The first ore shoot, encountered 30 feet southwest of shaft, is 70 feet in length and averages 3 feet in width. Between this ore shoot and the second one is 60 feet of barren ground. The second shoot is 60 feet in length and averages 3 feet in width. The vein quartz carries free gold, associated with pyrite and arsenopyrite. The ore mined from these ore shoots is reported to average $25 to $40 per ton in gold. The ore shoots developed on 100-foot level have been stoped to the 50-foot level. It is planned to sink the shaft to the 200-foot level. The other veins have been prospected by shafts to depths of 40 and 80 feet.

Mine equipment consists of a 6-horsepower Fairbanks-Morse gasoline single-drum hoist, an Ingersoll-Rand 8- by 4½- by 8-inch compressor, driven by an automobile engine; a Leyner drill sharpener, and an Ingersoll-Rand Imperial type (10- by 10-inch) (8½- by 10-inch) compressor. Ore is hoisted in a 1-ton car to a grizzly, then goes to a 6- by 8-inch Blake crusher and 40-ton ore bin; from the bin Challenge ore feeders deliver it to two batteries of five 1,250-pound stamps, driven by a Harris Industrial Motor. Crushed ore passes through a 40-mesh screen to the amalgamation plates. Tailing flows to pond. Recovery by amalgamation is $15 per ton. Water supply is from Jim Mack meadow, 3,000 feet east of shaft, through a 2-inch pipe line which rises 538 feet to storage tanks at the shaft. Pumping is done with a three-cylinder Triplex pump driven by a 6-horsepower Fairbanks-Morse gas engine. Two storage tanks with a capacity of 3,000 gallons each, and two with a capacity of 4,500 gallons each are provided. From 400 tons of ore milled, $5,700 was recovered. Three men are employed.

Lucky Boy mine (142), comprising three fractional claims, is in the Stringer mining district, adjoining the Sunshine on the west, and about 2 miles south of Randsburg; the owner is T. B. Peterson, Randsburg.

There are two veins in the schist; both strike east, one dips 45° N., and the other 65° S.; the widths range from a few inches to 2½ feet. The vein filling is quartz carrying free gold.

Development consists of a shaft sunk 185 feet on the south-dipping vein, with levels at 100, 145, and 185 feet. On the 100-foot level a drift extends 100 feet east; on the 145-foot level a drift extends 250 feet east; and on the 185-foot level a drift extends 125 feet east. On each level is a stope about 40 feet long by 3 feet wide. Ore is shipped to the Butte mill in Randsburg.

Three men are working.

Master Key group (145), of five claims, is in the Rand district about three-quarters of a mile east of Randsburg; the owner is Edward Herkelrath, Randsburg, California. Several northeast-trending veins have been found in the monzonite country rock, which has been intruded by rhyolite dikes. On the surface, these veins range from 1 to 3 feet wide. About $4,000 has been shipped from shallow openings on these veins.

The property is well situated and the owner believes that development work will expose a large, low-grade deposit.

The mine is now idle.

Middle Butte mine (147), consisting of 160 acres, is in the SW¼ sec. 16, T. 10 N., R. 13 W., S.B., on the east slope of the Middle Butte, 10 miles southwest of Mojave and 12 miles northwest of Rosamond. The elevation is 3,000 feet. The owner is Middle Butte Mine, Incorporated, care of Emory L. Morris, 601 First National Bank Building, Santa Ana, California.

This property was leased to Walter E. Trent (deceased) of Tonopah, Nevada, in 1935.

The vein, which occurs in rhyolite, strikes N. 26° W., dips 35° E., and has a width of 6 to 8 feet. The ore shoot was 150 feet long. The gold was free, finely disseminated through the brecciated vein quartz. The ore shoot was mined from the surface to 80 feet on the dip, 150 feet in length, and 8 feet in width. It is said to have averaged $70 per ton. Production was in excess of $150,000.

Considerable exploration work below this stope failed to disclose downward extension of ore shoot.

The mine is now idle.

Milwaukee mine (148) comprises 610 acres on the west slope of Hamilton Mountain, in sec. 16, T. 9 N., R. 13 W., S.B., 1½ miles west of Tropico and 7 miles west of Rosamond; the elevation is 2,850 feet. The owner is Milwaukee Mining Company, Milwaukee, Wisconsin.

The vein, which occurs in rhyolite, strikes east, dips 60° S., and has a width of 4 to 6 feet.

Development consists of five shafts and approximately 1,000 feet of drifts and crosscuts. Four of these shafts are caved. The most recent workings consist of an inclined shaft 250 feet deep, and a crosscut north on the 200-foot level. This shaft is west of and at a greater elevation than the old workings.

The mine is now idle.

Monarch mine (151) (Extension Ajax) consists of one claim, 740 feet wide by 1,687 feet long, in sec. 5, T. 10 N., R. 12 W., M.D., on the southeast slope of Soledad Mountain 4 miles south of Mojave. The elevation is 3,760 feet. The owner is Wilcox Estate, Bakersfield, California. During 1937 the property was under lease to Mojave Gold Shares, Incorporated, a Nevada corporation. During 1938-40 it was under lease to the Golden Ace Mining Company, E. Riveroll, Inglewood, president and manager. The property adjoins the Karma mine on the south. Two roughly parallel veins, the Ajax and the Karma, occur in silicified rhyolite. The general trend of the veins is N. 10° W., the dip 60° E.

On the south end of the property, the Ajax and Karma veins are cut off by a fault which strikes east. Development consists of a crosscut tunnel driven S. 74° W. for 587 feet; 294 feet west of portal, the tunnel intersected the Ajax vein, which at this point is 18 feet in width; 542 feet west of the portal it cut the Karma vein, which has a width of 45 feet. About 400 feet north of the crosscut, a tunnel, trenches, and open cuts have been made along the Ajax, exposing 18 feet of quartz, which is reported to average $5 per ton in gold and silver.

Old Cowboy mine (156), embracing four claims, is in secs. 28 and 29, T. 30 S., R. 33 E., M.D., south of Caliente Creek, on a ridge between Indian and Studhorse Creeks, about 12 miles east of Caliente, at an elevation of 3,100 to 4,000 feet. The owner is Clarence G. Talleur, Carson City, Nevada; the property is under lease to Basic Metals, Limited., Ray C. Stoner, Chas. H. Kidder, H. V. Burgard, general partners, 2453 North Beachwood, Los Angeles. This property adjoins the Gold Peak on the north.

The mine was developed and operated in the early part of the twentieth century, at which time 70 cars averaging $125 per ton were shipped.

Most of the country rock is granodiorite, but the immediate walls of the vein are quartz porphyry. The vein has a general east strike and dips 45°-50° S. The width between walls is approximately 12 feet. The ore stoped, on the hanging-wall side, averaged about 3½ feet in width. Vein filling consists of quartz and altered wall rock. Valuable minerals are silver sulphides, and pyrite which apparently carries silver. Silver constitutes about 95 percent of the valuable metal in the ore.

The mine is developed by six tunnels. The lower tunnel, No. 6, at an elevation of 3,120 feet, was driven 206 feet east. An 80-foot raise on the vein comes within 20 feet of connecting with a winze from tunnel No. 5, which was driven 600 feet east. Tunnel No. 4, at an elevation of 3,350 feet, was driven 500 feet east; No. 3, at an elevation of 3,450 feet, was driven 200 feet east; No. 2, at an elevation of 3,550 feet, was driven 200 feet east; and No. 1, at an elevation of about 3,620 feet, was driven eastward about 50 feet. Three ore shoots, aggregating approximately 300 feet in length, were developed in these workings. They were stoped from 18 inches to 6½ feet in width. This material all came from the hanging-wall side of the vein, and in many instances several feet of vein adjacent to the footwall side remains.

This property, in conjunction with the adjoining Gold Peak, is being developed by the lessee. The ore is to be treated in a leaching plant at Saugus, California.

Rand Gold Dredging Associates (175) Newton Cleveland (deceased), Norman Cleveland, Mayville C. Milton, and F. P. Adams, general partners, 315 Montgomery Street, San Francisco, leased from a number of different owners 1,000 acres in T. 29 S., R. 40 E., M.D., about 2 miles north of Randsburg.

This ground was tested by pits and drill holes. It was estimated that there were 5,000,000 yards of workable gravel from which gold and tungsten (scheelite) might be recovered. The gravel was found to extend to a depth of 45 feet, 10 feet of which would have to be stripped. As a result of these tests, a 3½ cubic foot bucket-line dredge was moved in from Roaring River, Shasta County. This dredge had a capacity of 2,500 to 3,000 cubic yards per day and would dig to a depth of 60 feet.

Four wells were drilled about 2½ miles north of Randsburg and there was some production of gold during 1943, after which the dredge was overturned. It was set upright about 2 years later, but operations were not resumed.

The property has been taken over by Foley Brothers, Incorporated, 900 New York Building, St. Paul, Minnesota. A 4 cubic yard Monighan and a Bodinson washing plant with capacity of 4,000 cubic yards per day were moved onto the property and were in operation in April 1948. Harry S. Dorriney is in charge of operations, and William Stolberg is dredge master.

Red Wing mine (179) comprising six claims, three of which are patented and three held by locations, is in secs. 26 and 35, T. 27 S., R. 40 E., M. D., in the Rademacher district about 3 miles north of Searles, a station on the Owens Valley branch of the Southern Pacific Railroad. The elevation is about 3,500 feet. The owner is Red Wing Mining and Milling Company, Fred G. Risley, president, office address 207 Haberfelde Building, Bakersfield, California.

The country rock, granitic and in places porphyritic, is traversed by fine-grained basic dikes. On Red Wing No. 1 claim a vein strikes N. 10° W. and dips 40° W. It has a width of a few inches to 3 feet. Vein filling is quartz and decomposed country rock. Where the vein is mineralized, it contains hard iron oxide. The quartz is vitreous and contains some pyrite and a little galena.

A shaft has been sunk on this vein 180 feet. At 170 feet, a drift has been driven north 50 feet.

On Red Wing No. 2 claim, a shaft is being sunk on the vein. It is down 25 feet.

Twelve men are employed.

Riveredge placers (183) comprises eight claims in sec. 19, T. 27 S., R. 32 E., M. D., 12 miles southwest of Isabella, at an elevation of 3,000 feet. The owner is P. W. Wilson, Post Office Box 8, Kern Canyon Route.

The placer claims are located along 3,000 feet of the Kern River channel between Greenhorn and Stovepipe gulches. The gold is fine and difficult to recover owing to a large amount of black sand concentrate.

Equipment consists of a 4-inch six-stage centrifugal pump. Sand and gravel are sluiced in 12-inch boxes equipped with riffles. The mine is worked intermittently during the summer months. Two men are employed.

Sky Line mine (191) consists of eight claims north of Pine Tree Canyon, about 15 miles north of Mojave and 3 miles west of the Owens Valley highway; the elevation is 4,000 feet. The owner is Edward Pyle, 4601 East 52nd Drive, Los Angeles, California.

The country rock is quartz monzonite. The principal vein strikes N. 85° W., dips 70°-75° NE., and has a width of 2 to 8 feet. The fissure is partly filled with quartz, auriferous pyrite, and very little free gold. The main development consists of two shafts. The east shaft is 250 feet deep with levels at 75, 140, and 250 feet. On the 250-foot level are drifts west 200 feet and east 210 feet. About 100 feet west of the shaft on the 250-foot level, a fault displaces the vein 60 feet to the north. The other shaft is 1,000 feet west of the east shaft. It was sunk on the vein 200 feet, and levels were run at 100 and 200 feet. About 1,200 feet north of this vein, a parallel vein crops out, its maximum width being 30 feet. It has been developed by a shaft 100 feet deep.

A mill was erected 1½ miles down the canyon from the mine. It consisted of a No. 2½ Wheeling jaw crusher, a 5- by 4-foot Marcy ball mill, a simplex Dorr-type classifier, a 6-foot K & K flotation rougher cell, a 6-foot K & K cleaner cell, and a Wilfley table. Capacity was about 40 tons per day. The mill has been dismantled and removed from the property.

The mine is now idle.

Stellar group of claims (194) is in the Rademacher district, half a mile southeast of Indian Valley Wells about 6 miles north of Searles, a station on the Owens Valley branch of the Southern Pacific Railroad; the owners are Ray Young, Mojave, and Ross Hank, Burbank, California.

The granitic rock of these claims is traversed by numerous dikes, principally rhyolite. Most of the dikes strike N. 30° W. The vein strikes N. 60° E. and dips 65° SE. It crosses the dikes and the ore occurs at or near these intersections. The vein has a maximum of 4 feet, and averages about 2 feet, in width.

Development consists of three shafts, 80, 110, and 200 feet deep. Of these, the 200-foot shaft is open to a depth of 80 feet only. The others are inaccessible. On the 50-foot level, a drift has been driven southwest 150 feet. This drift exposed an ore body 20 inches wide and 100 feet long, which was reported to carry $36 per ton.

The mine is now idle.

St. John mine (196) comprising eight claims unpatented and 160 acres in fee, is 16 miles south of Weldon, in sec. 33, T. 28 S., R. 35 E., secs. 3 and 4, T. 29 S., R. 35 E., and sec. 22, T. 28 S., R. 35 E., M.D. The elevation is 5,100 feet. The owner is Karl Struss, Hollywood, California. The property is under lease to Ross W. Prout and W. H. Curtis of San Fernando, California.

This is an old property which was worked in the early seventies by Senators Jones and Stewart of Nevada. Originally there were two mills near Tunnel Springs, the tailing from which has been cyanided; it was reported to yield $7 to $15 per ton.

The country rock is granodiorite. In addition to several aplite dikes 2 to 3 feet wide, there is a monzonite dike 3 to 20 feet wide. The vein, which is in a fault fissure, accompanies the monzonite dike; the general strike is N. 50° W.; the dip ranges from 32°-42° S.

Vein filling is quartz and altered monzonite; metallic minerals are free gold, auriferous pyrite, stibnite, some arsenopyrite, and a very little galena. The vein is faulted in many places both longitudinally and transversely. One system of transverse faults trends east and dips vertically; the other trends N. 75° E. and dips 55°-60° S. The longitudinal faults are approximately parallel to the vein and dip 30°-60° S. They are both post mineral and premineral. Tranverse faults are largely post mineral. Displacement ranges from 3 to 150 feet.

Property was developed by three shafts. The westernmost or main shaft is 600 feet deep. At a point 175 feet east is a 350-foot shaft, which connects at the 300-foot level with a third shaft which was 160 feet farther east. Development work was carried on through the 350-foot shaft. The 350-foot level was under water. Pumping was done 15 feet above this level with a No. 6 Cameron pump driven by air. On the 300-foot level a drift was driven 135 feet northwest from the shaft, at which point old workings were encountered. Some good ore, a faulted segment of that formerly worked, was found in this drift.

Equipment at the mine consisted of a 160 cubic foot Worthington portable compressor and gasoline hoist.

The ore was taken by trucks to the mill, about 500 feet west of Tunnel Springs. Ore went from a 30-ton bin through a $\frac{3}{4}$-inch screen, to a 7- by 10-inch jaw crusher, then to a hopper by belt feeder, to an elevator which delivered it to a 4- by 4-foot conical ball mill, with 10 inches of face at the larger end covered with a 24-mesh screen. Pulp from ball mill went to 12- by 36-inch amalgamating plate, then to Denver Equipment Company jig. Tailing was treated on 40-inch by 10-foot amalgamating plate. Hutch product went to 18- by 48-inch amalgamating barrel with rods. Sluices from barrel were continuously discharged over plate for amalgamation. Mercury was added to barrel and discharged to specially built separator, tailing from which went over plate. Water was pumped from Tunnel Springs.

The property is now idle.

Sunrise, Jenny Lind and New World group (200) comprises three patented claims, 60 acres, in sec. 10, T. 28 S., R. 32 E., M.D., in Clear Creek mining district, 1 mile west of Havilah, at an elevation of 4,000 feet. The owner is Mrs. Hallah Miller, Havilah, California.

A series of parallel northeast-striking veins occur in the granitic country rock. These range in width from 12 inches to 2 feet. The mine is developed by several short tunnels at different elevations.

The mine is now idle.

Surprise group of mines (203) comprises two claims in the Green Mountain mining district in the Piute Mountains, in secs. 5 and 6, T. 29 S., R. 34 E., M.D., 12 miles south of Weldon, at an elevation of 7,000 feet. The owner is Ed George, Bodfish, California.

Two parallel quartz veins which occur in granite strike northeast, dip 75° NW., and have a width of 2 feet. They are developed by shallow shafts and open cuts. Deposits in Slate Creek, for a distance of a quarter of a mile below the outcrop of the veins, were worked as placers in 1860.

The mine is now idle.

Tropico Mines (205) [8]. This property, which includes the Tropico, Fairview, and Lida mines, comprises 11 patented claims, 220 acres and two 5-acre mill sites, situated in secs. 10, 11, 14, and 15, T. 9 N., R. 13 W., S.B., about 5 miles northwest of Rosamond, at an elevation of 2,800 feet. The owners are Burton Brothers, Incorporated, and H. Clifford Burton, Rosamond, California.

On this property are four productive, parallel fault-fissure veins in rhyolite. The veins strike east and dip 60° S. Although in places widths of 50 feet or more have been mined, most of the ore ranges from 3 to 10 feet in width. Either or both walls may have to be determined by assay. The rhyolite is in thin layers with distinct faces (probably joint planes, or the result of shearing) between the layers, dipping about 80° S. In a total length of 2,000 feet along the Home or Tropico vein, four faulted segments of what may be the same shoot of ore have each been mined for a length of about 400 feet. The barren 400 feet represents the displacement of three northwest-trending faults, projected on the plane of the vein. The vein filling consists of brecciated silicified rhyolite, for the most part, but west of the Kid shaft some of the best ore is an altered, brecciated granitic rock. The less altered rock forms the footwall. These isolated masses of granitic rock give the impression of having been floated in by the rhyolite.

The veins are cut by a series of northwest-striking faults, dipping south, and also by north-striking faults, dipping 60° W. Some geologists have estimated that the displacement along the normal fault or faults forming the vein fissures is as much as 800 feet.

Principal development work is on the Home vein and consists of three shafts. The Fairview shaft, which is the easternmost, has been sunk to about 770 feet on the vein. One thousand feet west, the Tropico shaft is down 775 feet on a 60° inclination. The vertical Kid shaft, 1,000 feet west of the Tropico, is 850 feet deep. The Kid shaft has been concreted to the 400-foot level. A fourth shaft, on the Lida vein, is 300 feet deep.

Eight levels have been developed in the Home vein. The 600- and 700-foot levels extend from the Fairview shaft to the Kid shaft. Total development approximates 18,000 feet.

In the Fairview, only the shrinkage method of stoping was used. It was also largely utilized to the 600-foot level in the other shafts, but below this level all stopes are filled. Slushers are used to distribute the fill and to deliver broken ore to mill holes in the stope.

---

[8] See also Julihn, C. E., and Horton, F. W., The Golden Queen and other mines of the Mojave district, California: U. S. Bur. Mines Inf. Circ. 6931, pp. 37-41, 1947.

A notable feature of this mine is the fact that on the 800-foot level (about 1,080 feet on the dip) the ore is of better grade than that which was mined from the levels above.

A four-stage centrifugal pump on the 750-foot level is pumping 190 gallons per minute; auxiliary triplex and centrifugal pumps, in stages, boost this water to the surface.

Since the mine was re-opened, after being shut down for 4 years by Order L-208, hoisting has been confined to the Kid shaft. It is one and one-half compartments, equipped with a 75-horsepower two-drum electric hoist. Ore is hoisted in a 2-ton skip, and a counterbalance is in the one-half compartment. The Tropico shaft has a 45-horsepower electric hoist; the Fairview has the same. The Lida shaft has a 15-horsepower hoist. Other equipment consists of three compressors driven by one 150-horsepower motor and two 75-horsepower motors.

A new and modern change house adjoins the Kid shaft hoisting room. The surface plant is complete with a blacksmith shop, storeroom, assay office etc.

The mill is just across the road from the portal of the crosscut to the Tropico shaft. Trucks deliver ore from the Kid shaft to grizzly, from which oversize goes to a 14- by 24-inch jaw crusher. Crusher product passes over Symons 1-inch screen and oversize goes to Symons cone crusher, where it is crushed to about 1 inch. This size is fed to an Allis-Chalmers 5- by 6-foot ball mill, in closed circuit with a Dorr duplex classifier (grid type). Grinding is to 30 to 60 mesh, depending on the ore. Overflow goes to a portable distributing drag classifier, underflow to six rectangular leaching tanks, 40 feet long by 14 feet wide by 4 feet high at one end, 10 feet high at other. The bottoms of these tanks are only 4 feet wide, and a filter is placed about 12 inches above the bottom. The channel thus formed facilitates sluicing. Slimes pumped from portable classifier by rubber-lined pump go to a 40-foot Dorr thickener then to five propeller-type agitators. Solution goes to a Merrill-Crowe precipitation plant. Capacity is 150 tons per day with crew of eight men.

About 1,000 tons per month are now being treated; 25 tons per day comes from the Tropico mine and the rest from shipments from Exposed Treasure and Yellow Dog mines in the Mojave district.

Production of the Tropico mine to date is approximately $3,000,000. Normally a crew of about 60 men is employed; at present 27 are working.

Uncle Sam mine (206) (Southern Cross) consists of seven claims in secs. 3 and 10, T. 28 S., R. 32 E., M.D., in Clear Creek mining district, 2 miles west of Havilah, at an elevation of 4,200 feet. The owners are Mrs. Ella M. West and L. L. Porter, Havilah, California.

Three parallel veins, which occur in the granitic country rock, strike northeast and dip 70° S. The main vein has a width of 6 to 20 feet and has a massive outcrop of quartz, which can be traced for a distance of 2,000 feet.

The lower tunnel is driven southwest in the hanging wall of the vein. Seventy-one feet above this tunnel is a crosscut 350 feet northwest. Seventy-five feet from portal the crosscut intersected No. 1 vein and a drift was run 230 feet northeast on it. At 245 feet from portal the crosscut intersected No. 2 vein and a drift was run 300 feet northeast. This vein has an average width of 3 feet. Vein filling is iron-stained quartz which carries pyrite and arsenopyrite. It is stated that samples taken at intervals along the two veins assayed from $10 to $35 per ton in gold.

The mine is now idle.

Valley View mine (208) comprises 16 claims of which the following are patented: Havilah, San Pedro, Arizona, and Monrovia. The property is situated in the Valley View mining district, on a ridge north of Clear Creek, in secs. 3 and 4, T. 28 S., R. 33 E., M.D., 6 miles southeast of Bodfish. The elevation is 6,200 feet. The owner is Valley View Mining Company, Albert Long Brown, president, Arthur Brown, secretary, and Robert A. Brown, superintendent, Los Angeles, California. Nine parallel quartz veins, which occur in granite, strike N. 50° E. and dip 40° NW. The widths range from 4 to 6 feet. No. 1 and No. 2 veins are developed by tunnels. Tunnel No. 1 is driven northeast on the vein 385 feet. No. 2 vein, which is 24 feet west of No. 1 vein, is developed by a tunnel driven northeast 90 feet. About 200 feet north of the portal of No. 1 tunnel a shaft is sunk on No. 1 vein to a depth of 90 feet. Ore developed in the above working is reported to have an average value of $20 per ton in gold. Mine-run ore was trammed to mill, which is equipped with four 1,500-pound Nissen stamps. Capacity is 80 tons through 40 mesh. The mine was operated from 1907-12. Production was $28,000.

The mine is now idle.

Watkins group of placer mines (213) comprises four 160-acre placer claims in the Goler mining district east of Goler Canyon, in El Paso Mountains, in sec. 35, T. 28 S., R. 39 E., M.D., 9 miles northwest of Randsburg. The elevation is 3,200 feet. The owner is W. P. Watkins, Randsburg, California.

Gravel occurs on Slate Gulch, which runs into Goler Canyon. The depth of gravel ranges from 12 to 20 feet. The bed rock is sandstone.

Two men are employed.

Whitmore mine (218) comprises 10 claims in the Mojave district in sec. 32, T. 11 N., R. 12 W., S.B., 3½ miles south of Mojave, at an elevation of 2,700 feet. The owner is Whitmore Mines, Incorporated, W. H. Brownfield, president, 2007 Wilshire Boulevard, Los Angeles, California.

Four roughly parallel veins occur along rhyolite porphyry dikes in the granitic country rock. Their general trend is N. 30° W. and dip is 60° E. The veins range in width from 2 to 6 feet.

Development consists of three shafts, 300, 280, and 100 feet deep. One shaft was sunk on the most westerly vein to a depth of 300 feet on an inclination of 75°, with levels at 100 and 200 feet. This shaft is in the vein for 225 feet, after which it is in the footwall. The vein developed on these two levels had an average width of 3 feet, and the assays in gold and silver are said to have ranged from $6 to $50 per ton. The 100-foot shaft was sunk on a vein which is 2 to 4 feet wide. The vein quartz, carrying free gold and some pyrite, is reported to have contained from $10 to $20 per ton.

The mine is now idle.

Windy mine (219) comprises 90 acres in sec. 34, T. 29 S., R. 40 E., M.D., in the Rand district, 1 mile northeast of Randsburg, at an elevation of 3,800 feet. The owners are T. C. Welsh, Los Angeles, and H. E.

Marsh, Torrance, California. The property was last operated by International Mining and Milling Company, A. G. Ilseng, president.

Several parallel veins occur in the schist. The ore is free milling.

Development consists of an inclined shaft 225 feet deep and a crosscut on the 200-foot level with a winze 100 feet deep. Levels were driven at 50, 100, 150, and 200 feet. Workings aggregate several thousand feet.

Property was equipped with 40-ton amalgamation and cyanide plant.

The mine is now idle.

Yellow Aster mine (220) comprises 47 patented claims and 6 unpatented claims, aggregating 796 acres, in secs. 34 and 35, T. 29 S., R. 40 E., and secs. 2 and 3, T. 30 S., R. 40 E., M.D., half a mile south of Randsburg. It is owned by Yellow Aster Mining and Milling Company, 650 South Grand Avenue, Los Angeles.

The discovery of this mine in 1895 marked the beginning of the town of Randsburg. Since that time there have been several stages of development and mill operation. The first ore mined was treated in a small mill at Garlock, 9 miles northwest of the mine. Later the ore was shipped to a mill at Barstow. In the late nineties, a 30-stamp mill was erected on the property. About 1900 a 100-stamp mill was built.

The mine was operated continuously from 1895 through 1918, when it was shut down, reopening in 1921, from which time until the latter part of 1933 fifty stamps in the mill were run on ore mined by lessees. From 1895-1934 approximately $10,000,000 was recovered from about 2,750,000 tons. The metals were recovered entirely by the use of both inside and outside amalgamation.

In October 1933 the property was taken over (under lease) by the Anglo-American Mining Corporation of San Francisco. After exhaustive tests, the mill was remodeled to treat the dumps and ores from the glory hole; and a 1,500-ton cyanide plant was built to treat the old tailing as well as that from the new mill. This operation ceased in about 1941; since then the property has been idle.

Total production has probably exceeded $12,000,000.

The property and its operations have been described many times. The most recent and perhaps the most detailed descriptions are by Hulin, Cooper, Frolli, Tucker, and Sampson.[9]

Yellow Dog mine (222) comprises eight claims in secs. 29 and 32, T. 11 N., R. 12 W., S.B., in the Mojave mining district, about 3½ miles south of Mojave, at an elevation of approximately 2,800 feet. The owner is the Yellow Dog Mining Company, Bert Fisher, president, Mojave, California. The property is under lease to Richard Moon and Roy Farley, Mojave, California.

The discovery of a high-grade outcrop on this property in 1922 stimulated interest in the district. The vein, which occurs in rhyolite porphyry, strikes north, dips 60° E., and has a width ranging from 8 to 10 feet. The high-grade mineralization occurs in quartz on the hanging wall. On the footwall, there is 6 to 8 feet of calcite vein filling.

---

[9] Hulin, Carlton D., Geology and ore deposits of the Randsburg quadrangle: California Min. Bur. Bull. 95, pp. 121-125, 1925.

Cooper, Corwin L., Mining and milling methods and costs at the Yellow Aster mine: U. S. Bur. Mines Inf. Circ. 6900, 21 pp., 1936.

Frolli, A. W., Open-pit mining and milling methods and costs at the Yellow Aster mine, Randsburg, California: U. S. Bur. Mines Inf. Circ. 7096, 46 pp., 1940.

Tucker, W. B., and Sampson, R. J., Current mining activity in southern California: California Div. Mines Rept. 36, pp. 38-43, 1940.

Development consists of a 60° inclined shaft sunk 300 feet with levels at 50, 100, and 200 feet. In these workings north of the shaft, an ore shoot 200 feet long by 6 feet wide was developed between the 100-foot level and the surface. About 420 feet south of this, a 55° inclined shaft has been sunk 240 feet, with levels at 50, 100, 150, 180, and 240 feet. Lessees are working in a raise in the footwall above the 150-foot level about 75 feet from the shaft. The vein material here consists of interlacing quartz and calcite crystals carrying visible free gold. Its width is approximately 2 feet. The raise is about 20 feet above the level. Shipments have been made to Burton Brothers at Rosamond and to the Butte mill in Randsburg. Three men are working.

Lead-Zinc

Blackhawk mine (230) comprises eight claims in Caliente Canyon in sec. 28, T. 30 S., R. 33 E., M.D., 14 miles northeast of Caliente, at an elevation of 3,000 feet. The owner is J. A. Darnell, Bakersfield, California.

The vein of lead-zinc ore which occurs on the contact of granite and limestone, strikes north, dips 70° W., and has a width of 4 to 6 feet. It is developed by tunnels 150 feet in length and was operated in 1945 by Pacific Atlantic Metals Corporation, Pasadena, California. Several cars of lead-zinc concentrates were shipped, the ore having been treated in the Amalia flotation mill, which has a capacity of 50 tons per 24 hours.

The property is now idle.

Tin

Hogan-Mallery tin deposit (Meek-Hogan) is on the south slope of the Tehachapi Mountains on Rancho La Liebre, in sec. 25, T. 9 N., R. 18 W., S.B., 6 miles northeast of Gorman, at an elevation of 3,000 feet. The owner is Tejon Ranch Company, Brodie Hamilton, president, 202 West First Street, Los Angeles. The property is under lease to Willard Mallery, Redondo Beach, and Dana Hogan, president of the Hogan Petroleum Company, 714 West Olympic Boulevard, Los Angeles.

After its discovery in the spring of 1942, considerable money was expended in the exploration of this deposit. In September of 1942, D. L. Lemmon and P. C. Bateman, geologists of the U. S. Geological Survey, made a preliminary examination of it. At intervals from February 1943 through September 1944, the deposits were mapped and studied in detail by L. R. Page and J. H. Wiese [10], also of the Geological Survey.

In the summer of 1944 a program of core drilling and surface exploration was completed by the U. S. Bureau of Mines. The exploration work by lessees was discontinued in the latter part of 1943.

Cassiterite occurs in limonitic gossan and recrystallized limestone, associated with magnetite, quartz, and minor amounts of chalcopyrite, pyrite, arsenopyrite, galena, cuprite, malachite, and secondary zinc minerals. Epidote, garnet, and tourmaline are the common gangue minerals that accompany cassiterite in the limestone. The ore deposit lies 250 to 500 feet northwest of the limestone-granite contact. Trenches have exposed a gossan ore body 350 feet in length by 25 to 75 feet in width.

The cassiterite occurs in limestone and hornfels formed by the intrusion of the granite. The general strike is east, and the dip of the limestone beds is 45° N.

---

[10] Page, L. R., and Wiese, J. H., Tin deposits of the Gorman district, Kern County, California: California Div. Mines Rept. 42, pp. 31-52, 1946.

Most of the cassiterite occurs in a body of limonitic material which covers an area of 16,000 square feet; however, the soil also contains appreciable quantities of cassiterite, as a result of weathering. The soil has an average thickness of 3 feet, and it is estimated by Page [11] that it covers an area of 30,000 square feet, just below the deposit, which may yield placer tin. It is reported to assay one-half to one percent tin. Specimens of ore carry as high as 30 to 55 percent tin. Mallery mined, sorted and shipped 6 tons of ore which is reported to average 40 percent tin.

Development consisting of two inclined shafts 20 feet deep, and 10 shafts 10 feet deep have in part outlined the ore body. A 45-foot shaft has been sunk on an inclination of 65° S. 35° E. From the bottom of the shaft an 18-foot crosscut is driven S. 15° E. At a depth of 22 feet below the collar of the shaft, a drift runs 8 feet along the contact N. 45° E., then 70 feet north, crosscutting the mineralized zone. There is a second inclined shaft, 210 feet east of the 45-foot shaft. This shaft is sunk 50 feet on an inclination of 75°. At the bottom of the shaft, a crosscut was driven southeast 22 feet, but no ore was exposed in these workings.

Approximately three-quarters of a mile east of the Hogan-Mallery mine is the Butler deposit. Here cassiterite occurs in limonitic gossan on the contact of granite and limestone. It is developed by a trench 100 feet in length. Samples cut from this trench are reported to have had an average of 0.59 percent tin.

Two miles west of the Meek-Hogan deposit in Crow Bar Gulch on the contact of limestone and granite, a limonitic outcrop is reported to carry cassiterite.

The property is idle.

Tungsten

The production of tungsten ore from Kern County began in the Stringer district in 1905. This district is 2 to 4 miles south of Randsburg on the southeast slope of the Rand Mountains. It is adjacent to the Atolia mining district in San Bernardino County. Until 1915 these two districts comprised the only tin-producing area in the state. Subsequent discoveries have been made in several localities within the county, notably in the Greenhorn Mountains west and south of Kernville, the Piute Mountains southeast of Kernville, and on the east slope of the Sierra Nevada northwest of Inyokern. In each instance, the ore is scheelite (calcium tungstate, $CaWO_4$), but its occurrence is not the same.

In the Stringer district, which has been essentially a gold producer, the quartz veins in the Rand schist carry scheelite and gold. Here the principal production of tungsten has come from placer deposits in Baltic Gulch.

In the Piute Mountains the deposits occur in veins in the granodiorite and at or near the contact of this rock with limestone or schist. On the east slope of the Sierra Nevada most of them occur at the contact of limestone and granitic dikes.

In general, the occurrence affects the minerals in the gangue. The contact deposits are in most places in tactite, whereas the veins that are largely quartz gangue are in the granitic rocks.

---

[11] Page, L. R., Meek-Hogan tin prospect, Kern County, California: U. S. Geol. Survey Preliminary Map, 1943.

The demand for tungsten was greatly increased during the war, resulting in more prospecting and development of tungsten deposits. The deposits have already been described in several published reports.[12] Only the deposits which were discovered or actively developed since these reports were written are described herein.

Each tungsten property in the county, together with its bibliography, appears in the tabulation printed herewith.

Basin View tungsten mine (246) comprises two claims situated on Piute Mountain in Clear Creek mining district, sec. 31 ?, T. 29 S., R. 33 E., 6 miles southeast of Havilah. The owners are M. J. Gusty and C. G. Steadfield, 1314 North Highland Avenue, Hollywood, California.

A quartz-garnet-epidote vein, carrying scheelite, occurs at the contact of granodiorite and limestone. It is developed by a shaft 15 feet deep, and trenches 150 feet long. The ore developed is 3 to 4 feet in width, and is reported to carry 1 percent WO_3. The mill has a capacity of 25 tons.

The property is idle.

Donlevy tungsten mine (254) (Orrell group) comprises 10 claims in the Green Mountain mining district in the Piute Mountains in sec. 14, T. 29 S., R. 34 E., M.D., 4 miles southeast of Claraville, at an elevation of 6,800 feet. The owner is Lee Orrell, Weldon, California. The property is under option to the Donlevy Development Company, Ross W. Prout, president and manager, San Fernando, California.

Two parallel quartz veins which occur in quartz diorite, strike N. 50° E., dip 60° SE., and have a width of 2 to 6 feet. Development consists of two tunnels. The upper tunnel was driven northeastward on the southeast vein a distance of 285 feet. Four ore shoots were developed each 2 to 4 feet in width, and 30 feet in length. The ore developed carries 0.65 to 2 percent WO_3. Ninety feet in elevation below the upper tunnel, a tunnel has been driven northeastward for a distance of 300 feet. Sixty-5 feet from the portal, a shoot of ore 100 feet in length with an average width of 2 feet was developed. Samples cut at intervals were reported to average 1 percent WO_3.

Mine equipment consists of a Rix Compressor with a capacity of 120 cubic feet, and two Ingersoll-Rand drills. The water supply is obtained from springs 2,800 feet west of the mine, near Grouse Meadow. The water is pumped by a triplex pump, through a 2-inch pipe line 2,800 feet in length, to a 5,000-gallon storage tank at the mine. Ore passes from a mine car to an ore pocket to a 6- by 8-inch Blake crusher then to a 20-ton fine-ore bin. From the ore bin it is fed to a Wheeler ball mill in closed circuit with a Dorr simplex classifier and from the classifier to two Deister tables.

---

[12] Tucker, W. B., and Sampson, R. J., Current notes on activity in the strategic minerals, Los Angeles field district: California Div. Mines Rept. 39, pp. 62-65, 1943.

Partridge, John F., Jr., Tungsten resources of California: California Div. Mines Rept. 37, pp. 286, 287, 290, 291, 300-305, 312-313, 1941.

Tucker, W. B., and Sampson, R. J., Recent developments in the tungsten resources of California: California Div. Mines Rept. 37, pp. 575-579, 1941.

Tucker, W. B., and Sampson, R. J., Current mining activity in southern California: California Div. Mines Rept. 36, pp. 9-82, 1940.

Tucker, W. B., and Sampson, R. J., Mineral resources of the Kernville quadrangle: California Div. Mines Rept. 36, pp. 332-333, 1940.

Miller, W. F., and Webb, R. W., Descriptive geology of the Kernville quadrangle, California: California Div. Mines Rept. 36, pp. 343-378, 1940.

Prout, J. W., Jr., Geology of the Big Blue group of mines, Kernville, California: California Div. Mines Rept. 36, p. 411, 1940.

Tucker, W. B., and Sampson, R. J., Gold resources of Kern County: California Div. Mines Rept. 29, p. 319, 1933.

Tucker, W. B., and Sampson, R. J., San Bernardino County: California Div. Mines Rept. 27, p. 342, 1931.

Tucker, W. B., Kern County: California Div. Mines and Mining Rept. 25, pp. 47, 62, 63, 1929.

Fink, Colin G., Tungsten: Mineral Industry 1925, vol. 34, p. 702, 1926.

Hulin, Carlton D., Geology and ore deposits of the Randsburg quadrangle, California: California Min. Bur. Bull. 95, pp. 121, 129, 132, 137, 1925.

Hess, F. L., and Larsen, E. S., Contact-metamorphic tungsten deposits of the United States: U. S. Geol. Survey Bull. 725, pp. 263-265, 1922.

Tucker, W. B., Kern County: California Min. Bur. Rept. 17, pp. 315-316, 1921.

Fink, Colin G., Tungsten: Mineral Industry 1915, vol. 24, p. 688, 1916.

Brown, G. Chester, Kern County: California Min. Bur. Rept. 14, pp. 494, 505, 507, 509, 510, 513, 514, 1914.

The property is now idle.

Hi-Peak mine, comprising 14 claims, is on the east slope of the Sierra Nevada about 19 miles south of Little Lake and 1 mile west of the Owens Valley highway, in sec. 10, T. 26 S., R. 28 E., M.D. The owners are J. M. Hoyt, Jr., Beverly Hills, and Mrs. C. C. Parma, Pasadena, California.

The country rocks are granodiorite and crystalline limestone. The limestone has been intruded by narrow granitic dikes which are now schistose. The veins, of which six or eight have been found on the property, occur at or near the contacts, strike northeastward and dip about 70° SE. They are 5 to 8 feet wide. The filling is largely altered wall rock, but on one or both walls, in many places, is a 6- to 8-inch streak, principally epidote plentifully sprinkled with scheelite. Throughout the center section of the veins the scheelite is more likely to be sparsely disseminated.

Development consists of two tunnels. The upper one, driven southwestward 280 feet, was in granite for about 120 feet, then passed into alternations of tactite and granitic schist without encountering ore. Approximately 100 feet below and several hundred feet north another crosscut has been driven southeastward 400 feet. Two hundred feet from the portal, a vein was encountered on which a drift was driven southwestward 200 feet and northeastward 100 feet to a shaft sunk 285 feet on an inclination of 45°. At the bottom of this shaft is a crosscut east 300 feet. Twenty-five feet east on this crosscut is a 30-foot winze. Some ore was stoped from a raise which was driven from the lower workings to the adit level. This ore together with some 250 tons shipped from development, is said to have averaged about 1 percent WO_3.

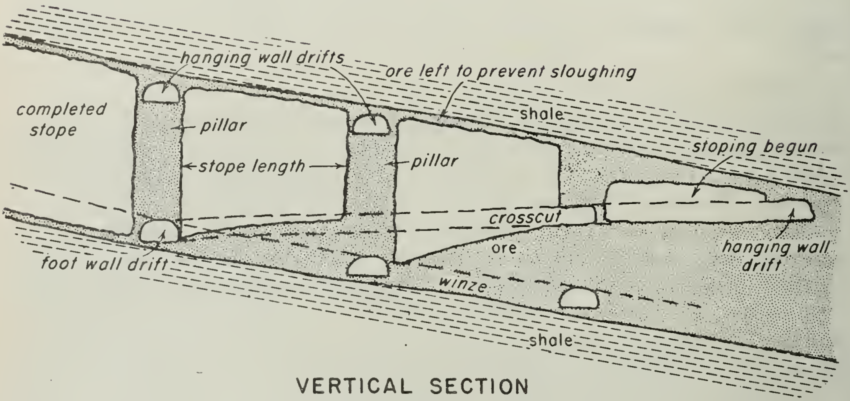
In 1944 a mill was built on the property consisting of the following: a Wheeling 9- by 15-inch crusher, a 12-inch belt conveyor, a 25-ton bin, a Hardinge weightometer feeder, and a double-deck vibrating screen, $\frac{1}{4}$-inch and 30 mesh. Plus $\frac{1}{4}$-inch and plus 30 mesh were fed to a 3- by 8-foot Marcy rod mill, minus 30 mesh wash fed to a Richards jig; the Marcy mill product was pumped back to the vibrating screen; tailing from the jig was treated on three Wilfley tables. The capacity was about 50 tons per 24 hours.

The property is now idle, and the mill has been removed.

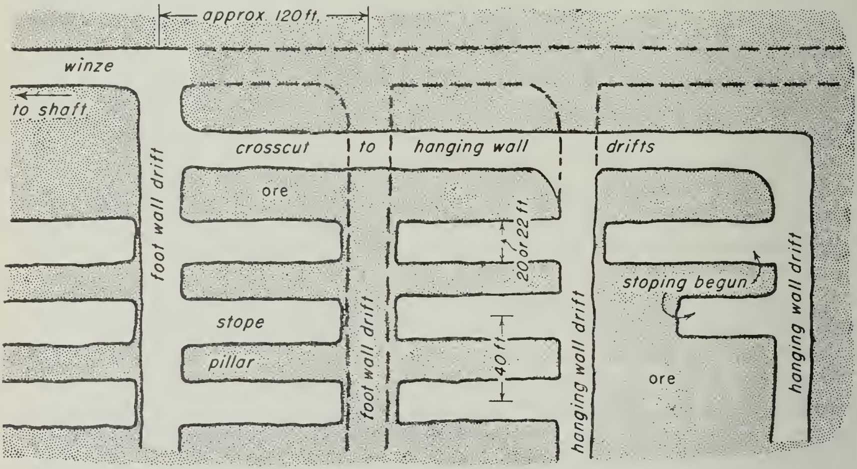
Nonmetallic Minerals

Borates

Pacific Coast Borax Company (298), F. N. Jenifer, president, J. M. Gerstley, vice-president and general manager, 510 West 6th Street, Los Angeles, C. G. Grim, general superintendent, Boron, California, has, since 1927, continuously been engaged in the development and mining of its deposits of borax (tincal) and kernite in T. 11 N., R. 7 and 8 W., S.B., at Boron, southeastern Kern County, about $3\frac{1}{2}$ miles northwest of Kramer, a station on the Santa Fe Railroad, 33 miles east of Mojave. The company owns the Baker mine and the West Baker mine. The latter



VERTICAL SECTION



PLAN OF WORKINGS AT ELEVATION OF CROSSCUT

Fig. 1. Diagrammatic plan and section of the Baker mine illustrating mining method. Not to scale.

includes what was once known as the Suckow borax mine. For early history of these deposits see the reports by Tucker and others.[13]

The deposits occur as lenticular masses of tincal and kernite enclosed in gray shale which strikes northwest. The dip of the Baker mine deposits ranges from practically horizontal in the central portions to a maximum of 17° SW at each end, with many rolls and local variations. The West Baker mine deposits dip from 6° to 8° NE.

Baker Mine. In this mine a deposit of tincal, which is in the hanging wall of the kernite deposit, is mined in the upper levels. The kernite deposit ranges in thickness from 8 to 115 feet. It does not pinch out, but ends abruptly along a fault-like contact with the shale. The deposits have been developed for a length of 2,900 feet along the strike and 600 to 1,400 feet along the dip, the 600 feet being at the northwest end. The pervious shale contains considerable moisture which gives it a tendency to cave. It is necessary to leave 3 to 4 feet of ore on each wall for support.

Development consists of three vertical shafts, two single-compartment shafts in sec. 24, T. 11 N., R. 8 W., each 470 feet deep, and the main three-compartment shaft in sec. 19, T. 11 N., R. 7 W., S. B., 540 feet deep with levels at 360, 420, and 480 feet. This shaft cut the ore at 360 feet. Development and operations below the bottom level are carried on through a winze sunk on the ore for a length of 1,000 feet. This winze is sunk at an angle to the dip so that its inclination will not exceed 9° (16 percent). It is put down on the footwall; drifts are driven on the footwall side at approximately 120-foot centers. At convenient intervals crosscuts are driven from the footwall to the hanging wall. Such a crosscut may have more than one hanging drift driven from it, each placed over a footwall drift below. These drifts have, to the present time, all been driven westward from the winze.

In the kernite, stopes 22 feet wide on 40-foot centers are worked. From a hanging-wall drift, a crosscut 22 feet wide is driven to a point below the next hanging drift up the slope; material between the drifts is stoped across the 22-foot width, the broken ore being removed by a three-drum dragline loader in the hanging-wall drift. When this is finished, an inspection platform is installed about 7 feet below the back of the stope. This platform consists of railroad rail, 7 feet from center to center, from rib to rib of the stope; 2- by 12-inch planks bolted together are supported by the rails along the sides of the stope. This serves as a platform from which men bar down the loose ore from the back and, with the aid of a bosun chair suspended from the platform, the ribs of the stope. When all is safe, underhand stoping is started and carried down in triangular shape until it is connected with the next footwall drift below. The broken material is removed by the dragline loader in the hanging drift above. The stope is completed from the footwall drift, as shown in the accompanying sketch. When completed, it is 22 feet wide in kernite and 20 feet wide in tincal; up to 100 feet or more high; and more than 100 feet long. The width being parallel to the strike, the height is from footwall to hanging wall and the length is along the dip.

---

[13] Tucker, W. B., Kern County: California Div. Mines and Mining Rept. 25, pp. 77-79, 1929.

Noble, L. F., Borate deposits in the Kramer district, Kern County, California: U. S. Geol. Survey Bull. 785, pp. 45-61, 1926.

Schaller, W. T., Borate minerals from the Kramer district, Mojave desert, California: U. S. Geol. Survey Prof. Paper 158i, pp. 137-173, 1930.

When a stope is finished, an 8-inch drill hole is put down from surface into the stope; this is reamed to 12 inches. Carryalls deliver the surface sand of the area to a stock pile at the hole. This material is pushed into the hole by a bulldozer. When the maximum cone at the bottom of the hole is reached, a high-speed fan fastened to a chute is attached to the bottom of the hole. This fan will completely fill the stope. If surface buildings make it impossible to place the hole over the stope, the hole is put into the top hanging drift. The sand is delivered to the opening into the stope by a belt conveyor and is distributed from this point by the fan.

Pneumatic drills are used in the kernite, electric drills in the tincal; 45 percent powder is used in blasting each material.

The dragline loads into 2½-ton automatic side dump cars which are hauled in 5-car trains by storage-battery locomotive to the winze, where they are hoisted and dumped into the shaft pocket. From the pocket, ore is hoisted in 1½-ton skips in balance.

West Baker mine is in sec. 14, T. 11 N., R. 8 W., S.B. The main shaft is about 1¾ miles northwest of the Baker shaft. It is 480 feet deep with a level at 380 feet. This shaft cut the ore at 310 feet. The ore consists of three lenticular masses of borax (tincal) interbedded with gray shale. The lower body is 45 feet thick and is overlain by 12 feet of shale; the middle body is 35 to 40 feet thick, and is overlain by 15 feet of shale; the upper body is 25 feet thick. The strike is northwest, the dip is 6° to 8° NE.

As in the Baker mine, development and mining operations are carried on through a winze below the 380-foot level. The same system of mining is used as in the Baker except that all stopes are 20 feet wide on 40-foot centers. The lower ore body is stoped first, then the center, and the top one last. This is done for convenience in filling. The ore is hoisted in 2½-ton skips in balance.

Each mine has a complete ventilation system similar to that of coal mines. This is accomplished by an exhaust fan in an auxiliary shaft, with doors and brattices in the workings, for directing the air current.

Development work in two mines aggregates several miles.

The ore is either crushed and shipped to the company's refinery at Wilmington or it goes through the concentrating mill at Boron, where concentrated products are manufactured for sale. During the war, upon authorization of the government, the company built and put into operation a boric acid plant at Boron.

The surface plant at each of the mines is modern and complete. The company operates a general store in which also is included the post office. Stress is placed on safety measures, a safety engineer is employed, and modern safety appliances are installed. Power is supplied by the Southern Sierras Power Company.

Cement

Monolith Portland Cement Company, Coy Burnett, president, A. G. Bartlett Building, Los Angeles, operates the only cement plant in Kern County. It is located at Monolith, about 4 miles east of Tehachapi.

The plant was originally built by the City of Los Angeles to manufacture cement used in the construction of the Owens Valley aqueduct.

The limestone for the plant comes from a deposit in sec. 14, T. 32 S., R. 33 E., M.D., about 3 miles east of Monolith. The plant and deposit have already been described by Tucker.[14]

Clay

The alluvial silt of the San Joaquin Valley, in the vicinity of Bakersfield, has been in use for many years for the manufacture of common brick. Deposits of pottery clay occur 4½ miles northwest of Rosamond and montmorillonite, bentonite, and halloysite clays occur in El Paso Mountains, north of Saltdale and Cantil, and in the Tehachapi Mountains northeast of Monolith. A deposit of fullers earth occurs 18 miles north of Bakersfield. Deposits of silt occur on Muroc and Rosamond dry lakes. The material is extensively mined for use in rotary mud. The clay deposits of Kern County are fully described by Dietrich.[15]

Amargo bentonite deposit (299) comprises 40 acres of patented land situated a quarter of a mile southwest of the Western Borate mine in sec. 26, T. 11 N., R. 8 W., S.B., 3 miles northwest of Amargo, a station on the Santa Fe Railroad, at an elevation of 2,400 feet. The owner is John Kennedy, Kennedy Minerals Company, 2550 East Olympic Boulevard, Los Angeles, California. A deposit of white bentonite occurs in gray shales. The bed is 20 feet thick with 2 to 4 feet of sand and clay overburden. The general strike of the bentonite bed is east, the dip is 5° S. The deposit is developed by an open cut 100 feet in length, 60 feet in width, and 15 feet in depth. The bentonite was worked during 1940 and 1941, and the material was shipped to the Kennedy Minerals Company of Los Angeles. Equipment consists of a bulldozer, and drying platforms.

The property is now idle.

Antelope Materials Company (301) (Macco Construction Company), John McCloud, president, 815 Paramount Boulevard, Claremont, California, is shipping clay from a 240-acre tract on Buckhorn dry lake in secs. 30 and 32, T. 9 N., R. 10 W., S.B., 12 miles east of Rosamond.

Material is excavated and loaded by a Haiss bucket loader and hauled by truck to the stock pile at Rosamond. From the stock pile, clay is elevated to Bucyrus and American dry pan grinders, then it goes to a St. Regis packer, or is shipped in bulk by truck or railroad car to various oil companies for use as drilling mud. Production is about 5,000 tons per month. Ten men are employed.

Filtrol Company's clay deposit (304) comprises 1,280 acres in sec. 2, T. 32 S., R. 34 E., and in sec. 34, T. 31 S., R. 34 E., M.D., 6 miles northeast of Monolith. The owner is Filtrol Company, Los Angeles. Exposures of bentonite occur in both the above mentioned sections. The bed of bentonite where exposed by open cuts, is 6 to 8 feet thick. The freshly exposed clay has a greenish color, but dry clay is white.

The property is now idle.

---

[14] Tucker, W. B., Kern County: California Div. Mines and Mining Rept. 25, pp. 70-72, 1929.

[15] Dietrich, Waldemar F., The clay resources and ceramic industry of California: California Div. Mines and Mining Bull. 99, pp. 88-90, 1928.

Jawbone clay deposit (305) (Williams) comprises 160 acres in secs. 27 and 34, T. 30 S., R. 36 E., M.D., 1 mile south of Jawbone Canyon and 8 miles west of Cantil, a station on the Southern Pacific Railroad. The elevation is 2,800 feet. The owner is American Mineral Company, 5601 South Boyle Avenue, Vernon, California, Edward Cummins, superintendent. The deposit of kaolin is in a belt of rhyolite that strikes northeast. The rhyolite is highly kaolinized and is white, being free of iron. The clay pit, which is 60 feet in diameter and has a 70- to 80-foot face, is in a box canyon. The clay has been excavated from the east side of the box canyon. The belt of rhyolite is about 2,000 feet in width and can be traced for several miles. Shipments amount to 100 tons per week. Equipment consists of a portable compressor, and a ¼-yard shovel. Material is loaded into trucks and hauled to the railroad for shipment to Los Angeles. Four men are employed.

Muroc silt deposit (309) is in secs. 21, 22, and 23, T. 10 N., R. 9 W., S.B., on Muroc Lake 20 miles east and 7 miles south of Mojave. The owner is Mojave Corporation, 1074 West Los Nietos Road, Los Angeles, California.

This clay, which is used as rotary mud in oil-well drilling, is excavated by power shovels after the removal of 4 to 6 feet of overburden. Excavations consist of two roughly parallel pits about 2,500 feet long, 50 feet wide, and 30 feet deep.

Material is loaded into trucks and hauled 2 miles east to a plant at Silt, a station on the Santa Fe Railroad. Trucks dump into an elevator boot; the elevator discharges onto ¼- and ⅛-inch screens; the oversize goes to a hammer mill then to an elevator boot; screenings go to a steel bin, then to a conveyor and railroad cars, or directly from the bin to trucks, or to a Bates packer, which is equipped with a dust collector.

Electric power is supplied to individual motor drives. Shipments are about 9,000 tons per month. The stock pile of several thousand tons at the plant, is recovered by a carryall.

Ten to twelve men are employed.

Riley clay deposit (310) is in sec. 19, T. 9 N., R. 11 W., S.B., on Rosamond dry lake, 3½ miles west of Rosamond. The owner is Southern Pacific Railroad; the property is leased to O. L. Riley Company, 1665 North Ventura Avenue, Ventura, California.

The clay excavated to a depth of 18 inches is loaded by a Haiss loader and hauled by trucks 1½ miles north to the mill. The plant consists of a hammer mill (with dust collector) and Bates packer. The plant is operated by a diesel engine. Material is used for oil-well mud. Two men are employed.

Feldspar

Rosamond feldspar deposit (318) comprises 12½ acres in the SW¼ sec. 6, T. 9 N., R. 12 W., S.B., 2 miles northwest of Rosamond. The elevation is 2,150 feet. The owner is Nelson W. Sweetzer, Rosamond, California. The outcrop of the pegmatite forms a small knoll on the floor of the desert, and covers an area 100 by 200 feet. The deposit of pink feldspar is interspersed with masses of quartz. It contains two large lenses of commercial spar; one lens 25 feet wide, has been mined for a length of 125 feet, and to a depth of 75 feet. The pegmatite strikes N. 45° W. The walls are medium-grained biotite granite. The feldspar is thoroughly fractured, and in mining, breaks along its cleavage to pea and nut size. It contains a certain amount of clay because of weathering. The clay is removed by drying feldspar on a platform in the sun, then running it through 20-mesh trommel, which removes the clay as fines. The feldspar analysis is as follows:

Al_2O_3	17.5%
K_2O	12.0%
Na_2O	4.0%
SiO_2	65.0%
Fe_2O_3	0.08%

The feldspar burns to a pure white color. The high potash and soda content of the spar renders it particularly suitable for glass making. To date the property has produced 2,500 tons of feldspar. Development consists of a vertical 75-foot shaft and 200 feet of drifts. Ore is hoisted and distributed on a drying platform which is 110 feet long and 10 feet wide. After the material is dried by the sun, it is delivered by dragline to a 25-ton ore bin; from the bin it goes by automatic feeder to a 5- by 4-foot pebble mill, then it is screened over a vibrating screen to 20 mesh, and elevated to a 50-ton fine-ore bin. Power to operate the plant is furnished by a 160-horsepower marine engine. Capacity of the plant is 12 tons per day of 20-mesh spar, which is shipped to the Los Angeles Chemical Company, Los Angeles.

Mine equipment consists of a 6-horsepower hoist and a 110-cubic foot Rix compressor. Three men are employed.

Gypsum

Extensive deposits of gypsum occur in Kern County along the lower foothills of the Sierra Nevada, in the San Joaquin Valley near McKittrick, in the vicinity of Lost Hills, and at the south end of Dry Salt Lake, near Cantil. The material is mined for use in the manufacture of cement and as a soil conditioner for agricultural lands. Demand for the latter has increased tremendously in the past 10 years. In 1944 approximately 400,000 tons was used on farm lands.

Cottonwood Creek deposits (319) occur in the valley of Cottonwood Creek, about 5 miles north of Pampas, a station on the Southern Pacific Railroad, in secs. 21, 27, 28, and 29, T. 29 S., R. 30 E., M.D. The owners are Oscar Rudnick, trustee, and P. Sumner Brown, both of Bakersfield.

These deposits are very extensive, occurring on both sides of Cottonwood Creek. The gypsum occurs both as a crust on the surface and as beds 20 inches to 5 feet thick inter-stratified with soft earthy shales. It was formerly mined as a soil conditioner.

These deposits are now idle.

Crystal Gypsum Company. Dave Crawford and Norman E. Yocum, Post Office Box 823, Oildale, have under lease 880 acres of gypsite-bearing land in secs. 27, 34, and 35, T. 32 S., R. 27 E., M.D., adjoining the Pacific Gypsum Company's deposit on the south and west. Small gypsite lenses were mined which ranged from 10 to 100 yards in diameter and from 6 inches to 2 feet in thickness. Stripping of a thin cover of soil and mining of the gypsite was done by bulldozer and carryall scraper. In the numerous shallow pits and prospect trenches only very small patches and unmined remnants of gypsite are exposed. The property was being operated in 1947, but was idle in December 1948.

Gypsum, Incorporated, (Pre-Built Homes Company, James K. Pierce, president, 2901 South San Pedro Street, Los Angeles), I. D. Watkins, general superintendent, Box 114, Rosamond, California, has a plant at Rosamond for the manufacture of wallboard and plaster, and for the preparation of gypsum for agricultural use. Gypsum is shipped in from Cantil and Maricopa, bentonite from Las Vegas.

From the 30,000-ton stock pile the gypsum is delivered by a conveyor to the Williams hammer mill then to one of three 60-ton steel bins, from which it is drawn to a mixing screen and Raymond mill. Air separation results in a product of 80 percent minus 200 mesh for plaster. A 135-foot tunnel and five decks for manufacture of plasterboard are now under construction.

In January 1947, 24 men were employed on construction.[16]

H. M. Holloway, Incorporated (320), H. S. Holloway, president, C. O. Knox, vice-president, Post Office Box 310, Lost Hills, California, has under lease from Occidental Land and Development Company and Richfield Oil Company, 1,423 acres in secs. 3, 10, 11, 13, 14, 15, and 24, T. 26 S., R. 20 E., M.D., 8 to 10 miles west of Lost Hills.

These surface deposits, overlain by an average thickness of 4 feet of sandy soil, are 4 to 23 feet thick. They are very extensive, covering several hundred acres. The material is shipped and used as mined. It is said to average 73.87 percent gypsum, having 13.7 percent combined sulphur. It is used for soil conditioning.

Stripping is done by carryall scraper; four RD4 tractors with BG 4-yard scrapers load material into trucks which haul it to users in all parts of the valley within a radius of about 150 miles. This deposit supplies more than two-thirds of the agricultural gypsum now used in the state. Eleven men are employed.

Monolith Portland Cement Company (321), Coy Burnett, president, 215 West 7th Street, Los Angeles, formerly worked a deposit of gypsum in sec. 31, T. 30 S., R. 22 E., M.D., about 2½ miles southwest of McKittrick. This 160-acre area was leased from Mr. Rankin of Bakersfield, California.

The deposit consists of both surface material and an east-dipping bedded deposit about 20 feet thick. A small area was stripped and surface material removed to a depth of about 3 feet, after which the bedded deposit was mined with shovel cuts. This deposit has a northwesterly strike, and easterly dip. The southeast pit is approximately 1,500 feet long, 30 feet wide, and 30 feet deep. Twelve feet of overburden was removed here. About half a mile northwest of this pit is a similar but a little wider pit. There are several smaller cuts.

The material was used by the Monolith Portland Cement Company and the Riverside Cement Company in the manufacture of cement.

Mojave Desert agricultural gypsum deposit (322) is in sec. 28, T. 30 S., R. 38 E., M.D., at the south end of Salt Dry Lake about 25 miles north and a little east of Mojave. A. D. Daly, Lancaster, California, is the operator.

---

[16] Since the above was written the plant has passed into the hands of Champco Minerals, Victor Weinbrenner, 5836 Whittier Boulevard, Los Angeles, who has leased it to J. B. Illo.

This is a surface deposit from which 8 to 10 inches of gypsiferous soil is stripped to remove plant growth. The deposit itself is 3 to 9 feet thick, and contains the equivalent of 78 percent gypsum. It has been intermittently worked for years, and about 200,000 tons have been shipped. Stripping is done by a bulldozer followed by a Haiss creeper-model loader which loads trucks for shipments. The loader cuts a trench 8 feet wide and has a capacity of 90 yards per hour.

Pacific Gypsum Company. W. D. Fowler, 230 Columbus Street, Bakersfield, has under lease a deposit of gypsum estimated to cover 240 acres. The deposit is in sec. 26, T. 32 S., R. 27 E., M.D., about 14 miles south of Bakersfield near the south margin of Kern Lake. It consists of several lenticular patches of gypsite 1 to 3 feet thick lying on sticky clay. The gypsite is overlain by a few inches to 2 feet of grass-covered soil.

Stripping and mining are done with two carryall scrapers which load the gypsite into trucks by means of a truck-loading ramp. The product is used in agriculture and a product guaranteed to contain 60 percent $CaSO_4 \cdot 2H_2O$ is shipped. Two men are employed at the mine.

Perlite

Perlite suitable for the manufacture of light-weight aggregate, loose-fill insulation, acoustical plaster, and other industrial purposes outcrops in a number of places in sec. 22, T. 31 S., R. 34 E., M.D. The perlite is dark gray and occurs as irregular flows associated with perlite breccia, rhyolite flows, tuffs, domes of dacite, and lacustrine sedimentary rocks of Miocene age.

The property is owned by Walter C. Eisenman, Box 76, Monolith, California. There has been no production of perlite from any of the deposits on this property.

Black Eagle and Grey Eagle perlite deposits (331) comprise two 160-acre placer claims in El Paso Mountains on the ridge north of Last Chance Canyon, in sec. 4, T. 29 S., R. 38 E., and in sec. 32, T. 28 S., R. 38 E., M.D., 7½ miles north of Saltdale, at an elevation of 2,850 feet. The owners are R. L. Meuer and Della Gerbracht of Randsburg, California. Several exposures of perlite occur on the Grey Eagle claim. In places basalt overlies the perlite and volcanic ash. On the south half of Grey Eagle placer claim is an exposure of perlite 200 feet in width. On Black Eagle placer claim are two exposures of perlite. On the south end of the claim is a large exposure which is 600 feet in width, 30 feet in thickness, and about 1,000 feet in length. Two men are employed on development work.

Pumice

Black Mountain pumice deposit (332) consists of one 160-acre placer claim in the Black Mountain mining district in El Paso Mountains, in sec. 32, T. 29 S., R. 38 E., M.D., 7½ miles north of Saltdale, at an elevation of 3,000 feet. The owners are R. L. Meuer and Della Gerbracht, Randsburg, California.

A large deposit of pumice occurs on this claim, 600 feet in width, 1,500 feet in length, and 50 feet in thickness. The pumice, capped by 6 feet of overburden, strikes north and dips 20° W. It is gray and contains inclusions of perlite. Two men are employed in development work.

Opal pumice deposit (335) consists of one 160-acre placer claim in El Paso Mountains, north of Last Chance Canyon, adjoining the Grey Eagle perlite deposit on the west, in sec. 4, T. 29 S., R. 38 E., M.D., 7 miles north of Saltdale, at an elevation of 2,900 feet. The owners are R. L. Meuer and Della Gerbracht, Randsburg, California. A bed of pumice 30 feet in thickness, 600 feet in width, and 3,000 feet in length occurs on this claim. The pumice is white to gray.

This deposit is idle.

Salt

Long Beach Salt Company (339), 2436 Hunter Street, Los Angeles, now operates a deposit formerly known as the California Salt Company deposit. It is in secs. 1 and 11, T. 30 S., R. 38 E., M.D., on Dry Salt Lake, about 6 miles northeast of Cantil.

The salt from the brines of the lake is recovered by solar evaporation. The vats, six in number, cover 69 acres. Water is pumped into a ditch 20 feet wide and 3 feet deep, which empties into the vats about half a mile west of the pumps. Three centrifugal pumps, one 10-inch, one 8-inch, and one 7-inch, raise the water 15 feet into the ditch. The salt is harvested by hand.

In recent years the refining for table use has been discontinued, because of the increased gypsum content. The product is now used for stock salt, hide, fish bait, chicken feed, and hay.

Three men are now employed.

Volcanic Ash and Pumicite

Calsilco Corporation (333) (Holly Cleanser) deposit of volcanic ash, comprising nine claims, is in sec. 33, T. 28 S., R. 38 E., and sec. 4, T. 29 S., R. 38 E., M.D., 10 miles north and east of Cantil, a station on the Owens Valley branch of the Southern Pacific Railroad. The owner is the Calsilco Corporation, George Reynolds, president, 445 South Amalia, Los Angeles; the property is under lease to Insulpum Corporation, 406 South Main Street, Los Angeles.

The deposit is 8 to 20 feet thick, white and very compact. It dips approximately 20° W.

The deposit has been developed by five open cuts. The two principal working places are 175 feet long, 20 feet wide, and 20 feet on the dip. The other three are approximately 30 feet long, 20 feet wide, and 20 feet on the dip.

The plant consists of a hammer mill, a bunker, a Williams roller mill, a $\frac{3}{8}$-inch screen, cyclone collectors, and a packing machine.

The following products are made: minus three-eighths plus 9 mesh for insulation of ceilings, minus 9 plus 40 mesh for insulation and acoustic plaster, minus 40 and 60 mesh used for scouring, and minus 325 mesh for wood filler, metallic paints, tooth powder etc. The capacity of the plant is 15 tons per day. Three men are employed.

Cudahy volcanic ash deposit (334) (Dutch Cleanser) comprises 160 acres in sec. 4 ?, T. 29 S., R. 38 E., M.D., about 8 miles north of Gypsite, a station on the Owens Valley branch of the Southern Pacific Railroad. The owner is Cudahy Packing Company, Los Angeles.

This operation has been discontinued after 25 years of continuous production.

White Castle pumicite deposit (337) consists of one 160-acre placer claim on a small butte on the north slope of El Paso Mountains, in sec. 32, T. 28 S., R. 39 E., M.D., 7 miles south of Inyokern, a station on the Owenyo branch of the Southern Pacific Railroad, and 2 miles south of Terese siding. The elevation is 3,500 feet. The owner is F. D. Shuck, Glendora, California. It is under lease to W. M. LeVocks, Anaheim, California. The exposure of pumicite is 600 feet in length, 300 feet in width, and 70 feet in thickness. It is overlain by basalt. Development consists of an open cut 50 feet in length on the east slope of the hill.

This deposit is idle.

Williams pumicite deposit (338) consists of one 160-acre placer claim on an extensive bed of pumicite which adjoins the White Castle pumicite deposit on the southwest in sec. 32, T. 28 S., R. 39 E., M.D., 8 miles south of Inyokern. The elevation is 3,500 feet. The owner is Tom Williams, Randsburg, California. An extensive bed of pumicite about 50 feet thick, and 600 feet long is developed by open cuts.

The property is now idle.

Tabulated list of mines in Kern County

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
1	Alice antimony	R. L. and Alice Coughran, Isabella, Calif.	2?	28S	32E	MD	Antimony	Idle. R. 13 p. 31; herein.
2	Amalia	Antimony Mines Co., R. C. Golden, Bodfish, Calif.	5	31S	36E	MD	Antimony	Idle.
3	Antimony Consolidated Mines	(Last known) Arthur Asher, Los Angeles, Calif.	5, 6	30S	36E	MD	Antimony	Idle. R. 14 p. 475; R. 25 p. 21; herein.
4	Antimony Peak (San Emigdio)	Kern Land & Development Co., Bakersfield, Calif.	9, 10	9N	21W	SB	Antimony	Idle. R. 8 p. 680; R. 10, p. 225; R. 14 p. 476; R. 25 p. 22; herein.
5	Jennette-Grant	Jennette-Grant Mining Co., Geo. Bergner, pres., Harrisburg, Pa.	10	28S	34E	MD	Gold, antimony	R. 36 p. 328; herein.
6	Mahary and Hougthawoth group		4	10N	15W	SB	Antimony	Idle. R. 20 p. 367; R. 25 p. 21.
7	Studhorse Canyon	Jessie L. Stubblefield and R. Ramey, Caliente, Calif.	5	31S	33E	MD	Antimony	Idle. Herein.
8	Tom Moore	Kern Land and Development Co., Bakersfield, Calif.	24	27S	33E	MD	Antimony	Idle. R. 10 p. 237; R. 14 p. 476; R. 25 p. 22; R. 36 p. 322.
9	Top of World	Henry G. Hubbard, Eagle Rock, Calif.	34	30S	32E	MD	Antimony	Idle. R. 39 pp. 61-62.
10	Wiggins	A. B. McAdams and J. M. Wiggins, Mojave, Calif.	8	31S	33E	MD	Antimony	Idle. Herein.
11	Contact	B. D. Standiford, Rosamond, Calif.	10	10N	15W	SB	Arsenic	Idle. R. 20 p. 368; R. 25 p. 22.

12	Apache (Holland)	L. B. Williams, 6127 Sepulveda Blvd., Van Nuys, Calif.	32	28S	39E	MD	Copper, gold, silver	Idle. Herein.
13	Copperola group	Della G. Gerbracht, Randsburg, Calif.	12, 13	29S	38E	MD	Copper	Idle. Herein.
14	Copper Basin group	William Schmidt, Randsburg, Calif.	15	29S	38E	MD	Copper	Idle. Herein.
15	French group	William French, Bakersfield, Calif.	3	29S	38E	MD	Copper, gold, silver	Idle. R. 17 p. 308; R. 25 pp. 23-24.
16	Gold Badger group (Zundra group)	Della Gerbracht, Randsburg	12	29S	38E	MD	Copper	Idle. Herein.
17	Orange Blossom	Mrs. Josie Bishop, H. H. Bishop, and H. D. Cook, Mojave, Calif.	6	30S	38E	MD	Copper	Idle. R. 25 p. 23; herein.
18	Silverado group	J. L. Hooper, Hobo Hot Springs, Calif.	9	27S	33E	MD	Copper	Idle. Herein.
19	Amalie	Mrs. J. J. Welbourne, Caliente, Calif.	22	30S	33E	MD	Gold	Idle. R. 12 p. 141; R. 13 p. 605; R. 14 p. 486; R. 17 p. 309; R. 25 pp. 24-25; R. 29, p. 287.
20	American Golden Eagle	Homer Bros., Havilah, Calif.	2, 10	28S	32E	MD	Gold	Idle. R. 14 p. 486; R. 25 p. 25.
21	Amy (Gold State)	Ed, George and Martin J. Errecart, Piute, Calif.	5, 32	29S 28S	34E 34E	MD MD	Gold	Idle. R. 29 p. 287; herein.
22	Baltic	Albert Ancker, Tehachapi, Calif.	1	30S	40E	MD	Gold	Idle. R. 14 p. 487; R. 25 p. 25; R. 29 pp. 287-288; Bull. 95 p. 128.
23	Barbarossa	Mrs. J. J. Wellbaun, Caliente, Calif.	29	30S	33E	MD	Gold	Idle. R. 14 p. 487; R. 25 p. 25; R. 29 p. 288.
24	Barnett	Mrs. E. C. Randolph, 1191 Beale Ave., Bakersfield, Calif.	16	30S	40E	MD	Gold	Idle. R. 29 p. 288.
25	Beauregard (see also Big Blue)	Kern Development Co., Kernville, Calif.	28	25S	33E	MD	Gold	Idle. R. M. (Kern) p. 8; R. 14 pp. 487-488; R. 20 pp. 36-40; R. 25 pp. 42-43; R. 29 p. 289; R. 36 pp. 28, 323.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
26	Beauregard Extension	Richard Boyd and Leonard Dimoush, Kernville, Calif.	28	25S	33E	MD	Gold	Idle. Herein.
27	Beehive	Kern Mines, Inc. (?) Bakersfield, Calif.	33?	28S	40E	MD	Gold	Idle. R. 25 pp. 25-27; R. 29 pp. 288-289; B. 95 p. 128.
28	Beryl group	Mrs. Josie Bishop, Mojave, Calif.	30	29S	37E	MD	Gold	Idle. R. 25 p. 35; herein.
29	Big Blue (includes Beauregard, Lady Belle, and Sumner)	Kern Development Co., C. S. Long, pres., Hayward, Calif.	28, 33	25S	33E	MD	Gold	Idle. R. 8 p. 313; R. 12 p. 142; R. 13 p. 186; 198; R. 14 pp. 488-489; R. 20 p. 40; R. 25 pp. 27-28; R. 29 pp. 289-291; R. 34 p. 11; R. 36 pp. 324, 379, 421; herein.
30	Big Dyke	Geo. Benko and Shay & Miller Estates, Randsburg, Calif.	1, 2	30S	40E	MD	Gold	R. 29 p. 292; R. 36 p. 29; herein.
31	Big Gold (West End)	John Kreta, Randsburg, Calif.	3, 4	30S	40E	MD	Gold	R. 29 p. 166; R. 25 p. 28; R. 29 pp. 291-292; B. 95 p. 130; herein.
32	Black Hawk	Geo. H. Clapp, Pittsburgh, Pa.	7 12	30S 30S	41E 40E	MD	Gold	Idle. R. 13 p. 187; R. 14 p. 489; R. 25 p. 29; R. 29 pp. 292-293; R. 36 p. 29; B. 95 pp. 130-131; R. M. (Kern) p. 17; P. R. 8 p. 46; herein.
33	Black Mountain	Chas. Brewer, Los Angeles, Calif.	10	29S	39E	MD	Gold	Idle. R. 25 p. 29.
	Blue Eagle (see Cactus Queen)							
34	Blue Jay	John Wyeis, Bodfish, Calif.	31	28S	34E	MD	Gold	Idle. Herein.

35	Blue Mountain (Dreadnot)	(Last known) Blue Mountain Mining Co., Rodney McCormick, Bakersfield, Calif.	11, 12, 14	25S	29E	MD	Gold	Idle. R. 12 p. 143; R. 13 p. 187; R. 14 p. 492; R. 17 p. 309; R. 25 p. 31; R. 29 p. 293.
36	Bond Buyer group	J. D. Voss, Garlock, Calif.	1	30S	37E	MD	Gold, silver, copper	Idle. R. 25 p. 51; R. 29 pp. 293-294.
37	Bowman (French Meadows) (109)	J. W. Walters, Isabella, Calif.	20	28S	34E	MD	Gold	Idle. R. 14 p. 512; R. 29 p. 293; herein.
38	Bright Star	Mrs. Lacy, San Francisco, Calif.	10	28S	34E	MD	Gold	Idle. R. 12 p. 142; R. 13 p. 187; R. 14 p. 490; R. 25 p. 30.
39	Bright Star	Unknown	12	25S	29E	MD	Gold	Idle. R. 14 p. 490.
40	Bryan	Dominic Domenghini, Bodfish, Calif.	19	29S	34E	MD	Gold	Idle. R. 29 pp. 272, 294.
41	Buckboard	Albert Ancher, Tehachapi, Calif.	10	30S	40E	MD	Gold	Idle. R. 24 p. 11; R. 29 pp. 294-295; R. M. (Kern) p. 9; herein.
42	Bull Run (see Big Blue)	Kern Development Co.						Idle. R. 20 p. 40; R. 36 p. 329.
43	Bully Boy	United Mines, Inc.	11, 12	30S	40E	MD	Gold	Idle. R. 19 p. 171; R. 25 pp. 30-31; R. 29 p. 272.
44	Burning Moscow	Piute Mining Co., W. H. White, pres., O. W. Crocker, sec., Seattle, Wash.	19	28S	35E	MD	Gold	Idle. R. 29 pp. 295-296; herein.
45	Burton, Brite, and Blank	Middle Butte Mine, Inc., c/o Emory L. Morris, 601 First Nat'l Bank Bldg., Santa Ana, Calif.	16	10N	13W	SB	Gold	Idle. R. 31 pp. 467, 471; herein.
46	Butte	Butte Lode Mining Co., 650 S. Grand Ave., Los Angeles, Calif.	36	29S	40E	MD	Gold	R. 29 p. 291; R. 34 p. 11; R. 36 pp. 11, 29; Bull. 95 p. 132; herein.
47	Butte Wedge (see Consolidated Mines)							
48	Cactus Queen	Cactus Mines Co., Roy W Moore, mgr., Pacific Mutual Bldg., Los Angeles, Calif.	17	10N	13W	SB	Gold and silver	R. 31 pp. 469; 471-472; R. 34 p. 11; herein.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
49	Caldwell	A. H. Kiester, Isabella, Calif.	18	26S	33E	MD	Gold	Idle. R. 14 p. 490.
49A	Chamberlain Group (see also Goler Canyon placers)	P. C. Chamberlain, 912 S. Figueroa, Los Angeles, Calif.	11	29S	39E	MD	Gold	Idle. Herein.
50	Chief	D. M. Dresser, Bakersfield, Calif.	22	27S	29E	MD	Gold	Idle. R. 14 pp. 490-491.
51	Claraville placers	A. D. Fulron, Cantil, Calif. (last known)	27, 34, 4	28S 29S	34E 34E	MD MD	Gold	Idle. R. 29 pp. 272-296.
52	Collar Button	W. B. Grant (?), Piute, Calif.	10	28S	34E	MD	Gold	Idle. R. 14 p. 491.
53	Commonwealth (see Big Blue)							
54	Confidence group	J. D. Voss, Saltdale, Calif.	31 (?)	29S	38E	MD	Gold	Idle. R. 29 pp. 296-297.
55	Consolidated Mines	Consolidated Mines Co., 1402 S. Wilton Pl., Los Angeles, Calif.	35	29S	40E	MD	Gold	Idle. R. 14 p. 491; R. 25 p. 31; R. 29 p. 297; B. 95 pp. 132-133.
56	Content (see Big Blue)	Kern Development Co., Kernville, Calif.	28	25S	33E	MD	Gold	Idle. R. 14 p. 489; R. 25 pp. 27-28.
57	Croesus group (Little Charlie)	Jack Biship, Trona, Calif.	6	29S	38E	MD	Gold	Idle. R. 29 pp. 315-316; herein.
58	Cunningham group (placer)	W. T. Cunningham, Wichita, Kan.	1, 2 27	29S 28S	39E 39E	MD	Gold	Idle. Herein.
59	David King group	Jess Arants, Roscoe, Calif.	10	29S	34E	MD	Gold	Idle. R. 29 p. 297.
60	Dead River placer	Charles Gibson, Isabella, Calif.	17	26S	33E	MD	Gold	Idle. R. 14 p. 491; R. 29 p. 297.

61	Dead Tree	J. C. and O. G. Geringer, Mojave, Calif.	21, 22	29S	34E	MD	Gold	Idle. R. 14 pp. 498-499; R. 25 p. 36.
62	Deer Hunter	M. D. Elliot, Piute, Calif.	20	30S	34E	MD	Gold	Idle. R. 14 p. 491.
63	Dearborn	J. C. and O. G. Geringer, Mojave, Calif.	36	29S	34E	MD	Gold	Idle. R. 29 pp. 272 and 297.
64	Donnie	A. M. Sargent, Weldon, Calif.	6	29S	34E	MD	Gold	Herein.
65	Double Standard	Mojave Mining & Milling Co., 261 I. W. Hellman Bldg., Los Angeles (last known)	5	10N	12W	SB	Gold	Idle. R. 14 pp. 491-492; R. 19 p. 158; R. 25 p. 31.
66	Drunkard's Dream	J. L. Stubblefield, E. A. Rosa and Earl Lambert, Havilah, Calif.	17, 18	28S	33E	MD	Gold	Idle. R. 29 p. 298; R. 30 p. 310; R. 36 p. 326.
67	Echo, Elephant, Gray Eagle	Goodwin J. Knight, 344 S. Las Palmas, Los Angeles, Calif.	6	10N	12W	SB	Gold	Idle. R. 14 p. 292; R. 19 pp. 158-159; R. 25 pp. 31-33; R. 29 pp. 298-299, 300; R. 31 pp. 472-474; U.S. Bur. Mines Inf. Circ. 6931, 1937.
68	Ederl group (McKeadney, Ophir, and Venus)	Ederl Mines, Ltd., Earl E. Lambert, pres., Havilah, Calif.	4, 9, 10	28S	32E	MD	Gold	Idle. R.M. (Kern) pp. 13, 14; R. 12 p. 146; R. 13 pp. 193, 194; R. 14 pp. 503, 506; R. 25 pp. 41, 44; R. 29 pp. 275, 299.
69	Elbow and Boulder (placer)	Unknown	33	27S	31E	MD	Gold	Idle. R. 29 p. 300.
70	Elephant (see Echo, Gray Eagle, etc.)							
71	Ellston	R. E. Ellston, Caliente, Calif.	8	29S	31E	MD	Gold	Idle. R. 14 p. 493; R. 25 p. 33; R. 29 p. 273.
72	Esperanza	Laura N. McFadden, 1310 S. Wilton Pl., Los Angeles, Calif.	5, 6	29S	35E	MD	Gold	Idle. R.M. (Kern) p. 10; R. 25 p. 33; R. 29 pp. 300-301.
73	Eureka	Mrs. Rayburn, Los Angeles, and Mrs. Garrison, Mojave, Calif.	6	10N	12W	SB	Gold	Idle. R. 34 p. 11; R. 36 p. 30; herein.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
74	Exposed Treasure and Desert Queen	Gordon Gray, San Diego, Calif.	32	11N	12W	SB	Gold	R. 13 pp. 193-194; R. 14 pp. 504-505; R. 19 pp. 160-161; R. 25 pp. 33-34; R. 29 pp. 301-302; herein.
75	Ferris (Golden or Jack Rabbit)	Calif. Engels Mining Co., Caliente, Calif.	34	30S	32E	MD	Gold	Idle. R. 13 p. 605; R. 14 p. 495; R. 25 p. 35; R. 29 p. 304.
76	Fine Gold (placer)	C. A. Irvine and W. A. Patterson	12 (?)	29S	39E	MD	Gold	Idle. R. 29 p. 302.
77	Four Jacks	Goodwin J. Knight, 344 S. Las Palmas, Los Angeles, Calif.	5 (?)	10N	12W	SB	Gold	Idle. R. 36 p. 30.
78	G. B.	Judge Paul J. McCormick, 2621 N. Vermont, Los Angeles, Calif.	1	30S	40E	MD	Gold	Idle. R.M. (Kern) p. 10; R. 13 p. 189; R. 14 pp. 493-494; R. 29 p. 273; R. 30 p. 315.
79	Gem	John Wilson Estate, San Francisco, Calif.	5	28S	31E	MD	Gold	Idle. R. 25 p. 34; R. 29 pp. 302-303.
80	Glen Olive	A. W. Stetson & Assoc., San Francisco, Calif.	33	27S	33E	MD	Gold	Idle. R. 14 p. 494; R. 25 p. 34; R. 36 p. 327.
81	Gold Bar (placer)	Mrs. Elizabeth J. Hercey, Los Angeles, Calif.	33	27S	31E	MD	Gold	Herein.
82	Gold Bag	A. DeMayo, Randsburg, Calif.	35	27S	40E	MD	Gold	Idle. R.M. (Kern) p. 11, 17; R. 29 pp. 273, 303; B. 95 p. 144.
83	Gold Cross (Eclipse, Edith, Paris, Standard)	Clarence G. Talleur, Carson City, Nev.	28	30S	33E	MD	Silver, gold	M.R. (Kern) pp. 10, 14; herein.
84	Gold Crown	Hiram E. Casey, 415 Spring Arcade Bldg., Los Angeles, Calif.	11, 12	30S	40E	MD	Gold	Idle. R. 14 p. 494; R. 25 p. 35; R. 29 p. 304.

85	Gold Hill	A. R. Greenslit, R. E. Baughman, John Holzgraffe, Los Angeles, Calif. (last known)	21, 22	28S	34E	MD	Gold	Idle. R.M. (Kern) p. 11; R. 29 pp. 273, 304.
86	Golden (see Ferris)							
87	Gold King	Chas. Ball, Alhambra, Calif.	4 (?)	28S	31E	MD	Gold	Idle. R. 25 p. 35; R. 29 p. 274.
88	Gold Pass	F. Reynolds, Randsburg, Calif.	35 (?)	27S	40E	MD	Gold	Idle. R. 29 p. 305.
89	Gold Peak (Zada)	Clarence G. Talleur, Carson City, Nev.	28	30S	33E	MD	Gold	R.M. (Kern) p. 17; R. 14 pp. 495-496; R. 25 p. 35; R. 29 p. 273; herein.
90	Gold Peak	(Last known) Gold Peak Mines, Ltd., G. A. Karpe, pres., Los Angeles, Calif.	6	29S	36E	MD	Gold	Idle. R. 29 pp. 305-306.
91	Gold Standard	J. E. Moreland, Bodfish, Calif., and Mrs. J. H. Potter Estate, Porterville, Calif.	12	28S	33E	MD	Gold	Idle. R. 36 p. 327; herein.
92	Golden Queen (Silver Queen, Queen Esther, Lodestar or Starlight, and Soledad Extension)	Golden Queen Mining Co., W. C. Browning, v.p. & g.m., 1211 Pacific Mutual Bldg., Los Angeles, Calif.	6, 7	10N	12W	SB	Gold	Idle. R. 31 pp. 472-473, 475-479, 482; R. 34 p. 10; R. 36 pp. 30-31, 33-34; U. S. Bur. Mines Inf. Circ. 6931, 1937; Am. Inst. Min. Met. Eng. Trans., vol. 126, 1937; herein.
93 (49A) (114)	Goler Canyon placers	(also see Chamberlain and Janney groups)	1 2, 3 10, 11	29S	39E	MD	Gold	Idle. R. 12 pp. 456-458; R. 13 p. 190; R. 29 pp. 273, 306-307; B. 92 p. 157; herein.
94	Good Hope	Consolidated Mines Co., 1402 S. Wilton Pl., Los Angeles, Calif.	35	29S	40E	MD	Gold	Idle. (See also Consolidated Mines.) R. 14 p. 496.
95	Good Luck	A. P. Tucker, Tulare, Calif.	16	27S	29E	MD	Gold	Idle. R. 12 p. 191; R. 14 p. 496; R. 25 p. 35; R. 29 p. 274.
96	Granite King	Chas. Burch, Mojave, Calif.	28	29S	36E	MD	Gold	Idle. R.M. (Kern) p. 11 R. 29 pp. 274, 307.
97	Gray Eagle	Goodwin J. Knight, 344 S. Las Palmas, Los Angeles, Calif.	6	10N	12W	SB	Gold	R. 14 p. 497. (See also Echo, Elephant, etc.)

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
98	Great Unknown (see Beryl No. 28)	Mrs. J. S. Bishop, Mojave, Calif.						Idle. R. 25 p. 35; R. 29 p. 274.
99	Greenhorn Caves placer	H. P. Bardshaw Estate, Los Angeles, Calif.	12,13,24, 19	27S 27S	31E 32E	MD	Gold	Idle. R. 29 p. 307; herein.
100	Grubstake placer	(Last known) Charles Keohn, Gypsite, Calif.	20 (?)	29S	38E	MD	Gold	Idle. R. 25 pp. 35-36 R. 29 p. 274.
101	Gum Tree	Goodwin J. Knight, 344 S. Las Palmas, Los Angeles, Calif.	32	11N	12W	SB	Gold	Idle. R. 36 pp. 31-32.
102	Gwynne (Gwynne-Jennette, Dearborn, and Mace)	Otto and Jack Geringer, Mojave, Calif.	21 22	29S	34E	MD	Gold	R. 12 p. 146; R. 13 p. 192; R. 14 pp. 498-499; R. 25 pp. 36-37; R. 29 pp. 307-309; R. 36 p. 32; R. 37 pp. 575-576; herein.
103	Hoegee (Haeger)	Mrs. Haeger (?), Los Angeles, Calif.	15	9N	13W	SB	Gold	Idle. R. 25 p. 36 (Haeger).
104	Hanover	Piute Mines, Ltd., J. W. Steele, agt., 206 S. Spring St., Los Angeles, Calif.	21 22	29S	34E	MD	Gold	Idle. R. 29 p. 309; herein.
105	Helene Galvin	Wm. Nestell, Fred and Helene Burns, 4628 Forman Ave., North Hollywood, Calif.	5	28S	31E	MD	Gold	Idle. R. 29 p. 309.
106	Hub	D. R. Little, Glendale, Calif., and Fred Hockett, Lancaster, Calif.	4	31S	35E	MD	Gold	Herein.
107	Huntington	Harry F. Willey (?), Inyokern, Calif.	35 (?)	27S	40E	MD	Gold	Idle. R. 29 pp. 309-310.

108	Iconoclast	Coulston Estate, Pasadena, Calif.	25	27S	33E	MD	Gold	Idle. R. 13 p. 186; R. 14 p. 497; R. 25 p. 36; R. 36 p. 327.
109	French Meadows (see Bowman) (37)							
110	Illinois and Golden Bell	J. Peep, Bodfish, Calif. (last known)	16	27S	33E	MD	Gold	Idle. R. 14 p. 497; R. 29 p. 274; R. 25 p. 36; R. 36 p. 328.
111	Indian Queen	R. E. Dosworth, Tulare, Calif. (last known)	15	27S	29E	MD	Gold	Idle. R. 14 p. 497; R. 25 p. 36; R. 29 p. 274.
112	Indian Wells Valley	Geo. and C. E. Albertson, Inyokern, Calif.	26 (?)	27S	40E	MD	Gold	Idle. R. 29 pp. 274, 310.
113	Iron Hat	Wm. Schmidt, Randsburg, Calif.	1	29S	39E	MD	Gold	Idle. Herein.
114	Janney placer (see also Goler Canyon placers)	John Janney, Pioche, Nevada	2, 3, 10, 11, 23, 24, 25, 26	29S	39E	MD	Gold	Idle. Herein.
			4, 5, 8, 9, 10, 17, 18, 19, 20, 21, 30	29S	40E	MD		
115	Jeff Davis (see Big Blue)							Idle.
116	Jennette-Grant	Jennette-Grant Mining Co., Geo. Bergner, pres., Harrisburg, Pa.	4, 10	28S	34E	MD	Gold	Idle. R. 36 p. 328; herein.
117	Jennette (Gwynne-Jennette)	Otto G. and James C. Geringer, Mojave, Calif.	22	29S	34E	MD	Gold	(See Gwynne mine.)
118	Joe Walker	J. B. Haggin and Phoebe Hearst Estates, New York	7 12	29S 29S	33E 32E	MD	Gold	R. 8 pp. 317-318; R. 29 pp. 310-311; herein.
119	Josephine	Tom Smith, Bodfish, Calif.	34	27S	33E	MD	Gold	Idle. R. 36 p. 328; herein.
120	Josephine	W. Adams, Corinth, Miss. (last known)	2, 3, 4, 5, 8	25S	29E	MD	Gold	Idle. R. 12 p. 145; R. 13 p. 191; R. 14 p. 498; R. 25 p. 37; R. 29 p. 274.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
121	Juan Dosie	Martin J. Errecart, Piute, Calif.	22	30S	33E	MD	Gold	Idle. R. M. (Kern) p. 12; R. 12 p. 145; R. 13 p. 191; R. 29 p. 274.
122	Jumbo	P. C. Chamberlain, 912 S. Figueroa, Los Angeles, Calif.	2	29S	39E	MD	Gold	Idle. Herein.
123	Karma	E. L. Wegmann, Mojave, Calif.	6	10N	12W	SB	Gold	Idle. R. 14 p. 499; R. 19 p. 161; R. 25 p. 37; R. 29 pp. 274, 311; herein.
124	Kelso Creek placers	Andrew Miller, Sageland, Calif.	16	28S	35E	MD	Gold	Idle. R. 29 pp. 274, 311.
125	Keyes	Kern River Mining Co., A. A. Cash, sec., 2240 San Fernando Rd., Los Angeles, Calif.	26	26S	32E	MD	Gold	Idle. R. 12 p. 145; R. 13 p. 191; R. 14 p. 499; R. 25 pp. 37-38; R. 29 pp. 274, 311-312; R. 36 pp. 32-33.
126	King Solomon	Shipsey Mining Co., 600 Mound Ave., South Pasadena, Calif.	35	29S	40E	MD	Gold	R. M. (Kern) p. 12; R. 14 p. 500; R. 18 p. 266; R. 25 p. 38; R. 29 pp. 313-314; R. 34 p. 11; R. 36 p. 33, 328-329. B. 95 pp. 136-137; herein.
127	King Solomon (Pleasant View)	King Solomon Gold Mining Co. (last known)	9, 10	28S	33E	MD	Gold	Idle. R. 14 p. 500.
128	La Crosse	H. Putman, Los Angeles, Calif. (last known)	11	30S	40E	MD	Gold	Idle. R. 14 p. 500; R. 25 p. 39.
129	Ladd	O. H. Ladd, Mojave, Calif.	36	11N	12W	SB	Gold	Idle. Herein.
130	Lady Belle (see Big Blue)		28	25S	33E	MD		

131	Laurel	John Hooper, Hobo Hot Springs, Calif.	26	27S	33E	MD	Gold	Idle. R. 29 pp. 274, 314-315; R. 36 pp. 329-330.
132	Lehigh Valley	P. R. Light and C. F. Walker, Inyokern, Calif.	22 (?)	27S	40E	MD	Gold	Idle. R. 29 pp. 274, 315.
133	Lida (see Tropico)	Burton Bros., Inc., Rosamond, Calif.	11	9N	13W	SB	Gold	
134	Little Angel	S. C. Smith (?), Havilah, Calif.	2	28S	32E	MD	Gold	Idle. R. 13 p. 192; R. 14 p. 501; R. 25 p. 39; R. 29 p. 274.
135	Little Bonanza	A. R. Lucey (?), Isabella, Calif.	35	26S	32E	MD	Gold	Idle. R. 12 p. 191; R. 14 p. 501; R. 25 p. 39; R. 29 p. 274.
136	Little Butte	Little Butte Mining & Milling Co., 612 Security Bldg., Los Angeles, Calif.	35	29S	40E	MD	Gold	Idle. R. 14 p. 502; R. 25 p. 39; R. 29 pp. 274, 315; B. 95 p. 137.
137	Little Joe	H. K. Patch, Los Angeles, Calif.	29	28S	34E	MD	Gold	Idle. R. 29 p. 316.
138	Locarno	N. V. Franceshi, Los Angeles (Caliente), Calif.	SE¼ 21, 28	29S	34E	MD	Gold, tungsten	R. 37 p. 576; R. 38 p. 329; R. 39 pp. 63-64; herein.
139	Lone Star	Lone Star Mining Co., J. E. Moreland, pres. & mgr., Bodfish, Calif.	7, 8	28S	34E	MD	Gold	R. 37 pp. 330-331; herein.
140	Long Tom	Long Tom M. & M. Co., Frank Hand, pres., 825 Yale St., Fresno, Calif.	21	27S	29E	MD	Gold	Idle. R. 11 p. 238; R. 14 p. 502; R. 25 p. 39; R. 29 pp. 275, 316-317.
141	Lost Keys	D. J. O'Connor, M. L. Rubbert, Inyokern, Calif.	34 (?)	27S	40E	MD	Gold	Idle. R. 29 pp. 275, 317.
142	Lucky Boy (see also La Crosse)	T. B. Peterson, Randsburg, Calif.	11	30S	40E	MD	Gold	Herein.
143	Maltby placer	J. Maltby, Moody, Calif.	20 (?)	25S	29E	MD	Gold	Idle. R. 29 pp. 275, 317.
144	Mammoth	Mammoth Mtn. Mining Co., J. H. Copelin, Isabella, Calif.	35	26S	32E	MD	Gold	Idle. R. 13 p. 193; R. 14 p. 502; R. 25 pp. 40-41; R. 29 pp. 275, 317-318.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
145	Master Key	Edw. Herkelrath, Randsburg, Calif.	36	29S	40E	MD	Gold	Idle. R. 36 p. 34; herein.
146	McKidney	D. Fergusin (?), Havilah, Calif.	9	28S	32E	MD	Gold	Idle. R. 13 p. 193; R. 14 p. 503; R. 25 p. 41; R. 29 p. 275.
147	Middle Butte	Middle Butte Mine, Inc., Emory L. Morris, 601 First Nat'l. Bk. Bldg., Santa Ana, Calif.	SW¼ 16	10N	13W	SB	Gold	Idle. R. 31 p. 48; herein.
148	Milwaukee	Milwaukee Mining Co., Milwaukee, Wis.	16	9N	13W	SB	Gold	Idle. R. 36 p. 34; herein.
149	Minnehaha	E. B. McGinnis, Randsburg, Calif.	2	29S	40E	MD	Gold	Idle. R. 14 p. 503; R. 25 pp. 41-42; R. 29 pp. 275, 319; B. 95 pp. 137-138.
150	Mohawk-Buddy	W. E. Russell, Cantil, Calif.	23	29S	36E	MD	Gold	Idle. R. 36 p. 35.
151	Monarch (Extension Ajax)	Wilcox Estate, Bakersfield, Calif.	5	10N	12W	SB	Gold	Idle. R. 36 pp. 34-35; herein.
152	Nellie Dent (see Big Blue)		28	25S	33E	MD	Gold	Idle.
153	North Sumner (see also Big Blue)	North Sumner Gold Mines, Inc., Kernville, Calif.	28	25S	33E	MD	Gold	Idle. R. 14 pp. 487-488; R. 20 pp. 36-40; R. 25 pp. 42-43; R. 29 pp. 320-321.
154	Norden placer	Yellow Channel Mining Co. (?), 616 N. Manhattan Pl., Los Angeles, Calif.	22	29S	40E	MD	Gold	Idle. R. 25 p. 43; B. 95 pp. 145-147; R. 29 pp. 275, 319-320.
155	Norman placer	Charles Norman and G. J. Holohan, Los Angeles, Calif.	36	29S	40E	MD	Gold	Idle. R. 29 p. 320.

156	Old Cowboy	Clarence G. Talleur, Carson City, Nev.	28	30S	33E	MD	Gold	Idle. R.M. (Kern) p. 14; R. 14 p. 505; R. 25 p. 43, R. 29 p. 275; herein.
157	Operator Consolidated (Phoenix, Operator, Divide)	Operator Consolidated Mines, 1304 Russ Bldg., San Francisco, Calif.	35	29S	40E	MD	Gold	Idle. R. 14 p. 507; R. 25 pp. 43-44; R. 29 pp. 275, 321; R. 36 p. 35; B. 95 p. 140.
158	Ophir	J. E. Waters, Havilah, Calif.	11	28S	32E	MD	Gold	Idle. R. 13 p. 194; R. 14 p. 506; R. 25 p. 44.
159	Opportunity	H. W., C. B., and George Ross, Isabella, Calif.	35 (?)	26S	33E	MD	Gold	Idle. R. 29 p. 321.
160	Oro Fino (see Summit placers)	D. A. Woodruff, 323 S. Hancock St., Los Angeles, Calif.	1, 12	29S	40E	MD	Gold	Idle. R. 25 pp. 44, 48-49; B. 95 p. 147.
161	Orphan Girl	O. A. Phillips, D. S. Spearman, Randsburg, Calif.	12	29S	40E	MD	Gold	Idle. R. 25 p. 44.
162	Pearl Wedge	Mrs. Grace Jewitt, Los Angeles, Calif.	11	29S	40E	MD	Gold	Idle. R. 25 p. 44; R. 29 p. 275.
163	Pennsylvania	W. B. Walker, Keyesville, Calif.	35	26S	32E	MD	Gold	Idle. R. 25 p. 45; R. 29 pp. 275, 322-323.
164	Phoenix (see Operator Consolidated)							
165	Pine Tree (American)	C. H. Claussenius, 1248 Ridgely Dr., Los Angeles, Calif.	4	11N	15W	SB	Gold, tungsten	Idle. R. 13 p. 194; R. 14 p. 506; R. 25 p. 45; R. 29 p. 275; R. 37 pp. 577-578; R. 38 p. 332.
166	Pinmore	Shipsey Mining Co. (?), 600 Mound Ave., South Pasadena, Calif.	25, 36	29S	40E	MD	Gold	Idle. R.M. (Kern) pp. 8, 14, 17, R. 14 p. 507; R. 18 p. 105; R. 29 p. 275.
167	Piute (see Tropico)	Burton Bros., Inc., Rosamond, Calif.	11	9N	13W	SB	Gold	R. 14 p. 512; R. 25 pp. 50-51.
168	Piute Consolidated	Piute Consolidated Mining Co.	13	28S	34E	MD	Gold	Idle. R. 14 pp. 506-507; R. 25 p. 45; R. 29 p. 275.
169	Polar Bear	Unknown	29	27S	33E	MD	Gold	Idle. R. 14 p. 507.

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
170	Poso	Poso Mining and Milling Co., E. W. McCutchin (?), Bakersfield, Calif.	30, 31	27S	28E	MD	Gold	Idle. R. 25 p. 45; R. 29 pp. 275, 323.
171	President	Unknown	4	27S	32E	MD	Gold	Idle. R. 14 p. 507.
172	Pyramid	P. J. Osdick (?), Red Mountain, Calif.	1 (?)	29S	40E	MD	Gold	Idle. R. 14 p. 508; R. 29 p. 275.
173	Queen Esther (see Golden Queen)	Harvey S. Mudd, Pac. Mutual Bldg., Los Angeles, Calif.	6	10N	12W	SB	Gold	R.M. (Kern) p. 14; R. 14 p. 508; R. 19 p. 162; R. 25 p. 46; R. 29 p. 275; R. 30 p. 408; R. 31 pp. 465, 468, 482; R. 36 p. 11.
174	Rand	G. E. Bennett, Caliente, Calif. (last known)	3	28S	32E	MD	Gold	Idle. R.M. (Kern) p. 14, 16; R. 14 p. 508; R. 29 p. 275.
175	Rand Gold Dredging Associates	Norman Cleaveland (lessee), 315 Montgomery St., San Francisco, Calif.	23, 24	29S	40E	MD	Gold, tungsten	Now being worked by Foley Bros. R. 36 p. 122; herein.
176	Rand placers	Yellow Aster M & M Co., Randsburg, Calif.	6, 9	29S	39E	MD	Gold	Idle. R. 29 p. 275.
177	Rattlesnake group	Mrs. J. S. Bishop, Mojave, Calif.	32 (?)	29S	38E	MD	Gold	Idle. R. 25 p. 59.
178	Red Hill	Kern Development Co., Kernville, Calif.	21	25S	33E	MD	Gold	Idle. R. 14 p. 509; R. 25 p. 46; R. 29 p. 275.
179	Red Wing	Red Wing M & M Co., Fred G. Risley, pres., 207 Haberfelde Bldg., Bakersfield, Calif.	26, 35	27S	40E	MD	Gold	Herein.
180	Reform	Mrs. Nora D. Coulston, Pasadena, Calif.	1, 12	28S	33E	MD	Gold	Idle. R. 29 p. 323.

181	Ricardo placers	Rudolph Hagen, Bakersfield, Calif.	2, 35	29S 30S	37E	MD	Gold	Idle. R. 12 pp. 456-458; R. 13 p. 195; R. 25 p. 46; R. 28 pp. 249-250; R. 29 pp. 323-324; R. 30 pp. 246-247.
182	Riches and Wealth placer	Earnest Griffith, Bakersfield, Calif.	19	26S	32E	MD	Gold	Idle. R. 25 pp. 46-47.
183	Riveredge placer	P. W. Wilson, P.O. Box 8, Kern Canyon Rte., Bakersfield, Calif.	19	27S	32E	MD	Gold	Idle. R. 29 p. 324; herein.
184	Rose	George King, Isabella, Calif. (last known)	31	26S	32E	MD	Gold	Idle. R. 14 p. 509.
185	Ruby	George Thacker, Bakersfield, Calif.	9, 16, 17	29S	31E	MD	Gold	Idle. R. 24 pp. 276; 324-326.
186	Rustler and San Diego	E. B. McGinnis and J. T. O'Leary, Randsburg, Calif. (last known)	2	29S	40E	MD	Gold	Idle. R. 14 p. 509; R. 25 p. 47; R. 29 p. 276.
187	Sailor Boy (Ben Hur)	Golden Queen Mining Co.	6	10N	12W	SB	Gold	See Golden Queen.
188	San Antonio	J. Martino, Bakersfield, Calif., Mrs. Lee, San Fernando, Calif.	22, 23	29S	36E	MD	Gold	Idle. R. 25 p. 47; R. 29 pp. 276, 326.
189	Santa Ana (Napoleon)	Geo. Carr, Bakersfield, Calif.	11	30S	40E	MD	Gold	Idle. R.M. (Kern) p. 13; R. 14 pp. 485, 509-510; R. 29 p. 276; B. 95 p. 144.
190	Sidney (White)	P. W. McAuliffe, 1516 State St., Los Angeles, Calif.	16, 17	30S	40E	MD	Gold	Idle. R. 14 p. 510; R. 25 p. 51; R. 29 pp. 276, 333-334.
191	Sky Line	Verne Moore Estate and Associates, Cantil, Calif.	15 (?)	31S	36E	MD	Gold	Idle. R. 36 p. 36; herein.
192	Southern Cross (Uncle Sam)	Mrs. Ella M. West and L. L. Porter, Havilah, Calif.	3, 10	28S	40E	MD	Gold	Idle. R. 14 p. 510; R. 25 p. 47; R. 29 pp. 331-333.
193	Stanford	Santa Ana Gold Mines Co., S. Montgomery, Randsburg, Calif.	1, 11, 12	30S	40E	MD	Gold	Idle. R. 14 p. 510; R. 25 p. 47.
194	Stellar	Ray Young, Mojave, Ross Hand, Burbank, Calif.	23	26S	40E	MD	Gold	Idle. R. 29 pp. 276, 327; herein.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
195	St. Charles	Kate Reese Est., Mrs. Gus Miller, Havilah, Calif.	33 (?)	27S	32E	MD	Gold	Idle. R. 13 p. 196.
196	St. John	Karl Struss, Hollywood, Calif.	33 3, 4	28S 29S	35E 35E	MD MD	Gold	Idle. R.M. (Kern) p. 15; R. 25 p. 47; R. 29 pp. 276, 327-328; R. 36 p. 37; herein.
197	St. Lawrence	Frank W. Royer, Red Mountain, Calif.	1	30S	40E	MD	Gold, silver	Idle. R. 29 p. 170; R. 25 p. 59; B. 95 p. 143.
198	Summit gold placers (Summit diggings)	A. L. Cram, Searles, Calif.	1, 2; 6	29S 29S	40E 41E	MD MD	Gold	Idle. R. 25 pp. 48-49; R. 29 pp. 276, 328; B. 92 p. 156; B. 95 pp. 147-148.
199	Sumner and North Extension	Kern Development Co., Kernville, Calif.	28	25S	33E	MD	Gold	Idle. (Part of Big Blue) R. 14 pp. 487-488; R. 20 pp. 36-40; R. 25 pp. 42-43; R. 29 pp. 276, 320, 321.
200	Sunrise-Jenny Lind and New World	Mrs. Hallah Miller, Havilah, Calif.	10	28S	32E	MD	Gold	Idle. Herein.
201	Sunset	C. E. Pierrel, Bodfish, Calif. (last known)	10	27S	32E	MD	Gold	Idle. R. 13 p. 197; R. 14 p. 511; R. 29 p. 276.
202	Sunshine	T. W. Atkinson Estate, 301 Holly Ave., Compton, Calif.	11	30S	40E	MD	Gold	Idle. R.M. (Kern) p. 15; R. 14 pp. 512, 522; R. 29 pp. 276, 329; B. 95 p. 144.
203	Surprise group	Ed George, Piute, Calif.	29	28S	34E	MD	Gold	Idle. R. 29 pp. 276, 329; herein.
204	Trestle	Unknown	18	29S	34E	MD	Gold	Idle. R. 14 p. 512; R. 29 p. 276.

205	Tropico	Burton Bros., Inc., Rosamond, Calif.	10, 11, 14, 15	9N	13W	SB	Gold	R. 14 p. 512; R. 25 p. 50-51; R. 29 pp. 276, 331; R. 31 pp. 482-484; R. 36 pp. 37-38; herein; U. S. Bur. Mines, I. C. 6931 pp. 37-41, 1937.
206	Uncle Sam (see also Southern Cross)							Idle. Herein.
207	Urbana and Frank (see Big Blue)		28	25S	33E			
208	Valley View	Valley View Mining Co., A. L. Brown, pres., Los Angeles, Calif.	3, 4	28S	33E	MD	Gold	Idle. Herein.
209	Voss Consolidated	J. D. Voss, Garlock, Calif.	1	30S	37E	MD	Gold	Idle. R. 25 p. 51; R. 29 p. 276.
210	Wall Street group	Edw. Doble, Piute, Calif. (last known)	18	28S	34E	MD	Gold	Idle. R. 29 pp. 276, 333.
211	Wall Street		35	27S	40E			Idle. R.M. (Kern) pp. 16, 19. (Probably same as Huntington)
212	Warrington (Little Angel)	S. L. Simmons and S. F. McDonald, Havilah, Calif.	3 (?), 4	28S	32E	MD	Gold	Idle. R.M. (Kern) p. 16; R. 29 p. 333.
213	Watkins group	W. P. Watkins, Randsburg, Calif.	35	28S	39E	MD	Gold	Idle. Herein.
214	Wedge (see Exposed Treasure)		32	11N	12W	SB	Gold	R.M. (Kern) p. 16.
215	White (see Sidney) (190)							
216	White Star	E. A. Braden, Bodfish, Calif. (last known)	11	27S	32E	MD	Gold	Idle. R. 14 p. 513; R. 25 p. 51; R. 29 p. 276.
217	White Star	P. Erdman, Inyokern, Calif.	28 (?)	27S	40E	MD	Gold	Idle. R. 29 pp. 276, 334.
218	Whitmore	Whitmore Mines, Inc., W. H. Brownfield, 2007 Wilshire Blvd., Los Angeles, Calif.	32	11N	12W	SB	Gold	R. 19 pp. 152-153; R. 25 p. 52; R. 29 pp. 277, 334-335; R. 31 pp. 484-485; R. 36 p. 38; herein.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
219	Windy	T. C. Welch, Washington Bldg., Los Angeles, H. C. Marsh, 1637 221st St., Torrance, Calif.	34	29S	40E	MD	Gold	Idle. R. 14 p. 513; R. 25 pp. 51-52; R. 29 p. 335; herein.
220	Yellow Aster	Yellow Aster Mining & Milling Co., Randsburg, Calif.	34, 35 2, 3	29S 30S	40E 40E	MD MD	Gold	Idle. R. 13 p. 194; R. 14 p. 514; R. 25 pp. 53-54; R. 29 pp. 277, 335-338; R. 36 pp. 38-43; B. 95 pp. 121-125; U. S. Bur. Mines Inf. Circs. 6900 and 7096, 1940; herein.
221	Yellow Boy	Unknown	18	28S	34E	MD	Gold	Idle. R. 36 p. 328.
222	Yellow Dog	Yellow Dog Mining Co., Bert Fisher, pres., Mojave, Calif.	29, 32	11N	12W	SB	Gold	R. 19 pp. 163-164; R. 25 p. 55; R. 29 pp. 277, 338-339; R. 31 p. 485; herein.
223	Yellow Dog Extension	Yellow Dog Extension Mining Co., Mojave, Calif. (last known)	33	11N	12W	SB	Gold	Idle. R. 19 p. 164; R. 25 p. 55-56; R. 29 p. 277.
224	Yellow Treasure	A. DeMayo, Searles, Calif.	35	27S	40E	MD	Gold	Idle. R. 29 p. 339.
225	Zenda	Zenda Gold Mining Co., I. W. Hellman Bldg., Los Angeles, Calif.	30	30S	33E	MD	Gold	Idle. R. 14 p. 515; R. 20 pp. 41-42; R. 25 p. 65; R. 29 pp. 277, 339.
226	Iron Mountain	Unknown	10, 15	26S	29E	MD	Iron	Idle. R. 14 p. 516; R. 25 p. 56.
227	Mount Breckenridge	Unknown	4	29S	31E	MD	Iron	Idle. R. 14 p. 516; R. 25 p. 56.
228	San Emidio	Unknown	17	9N	21W	SB	Iron	Idle. R. 14 p. 516; R. 25 p. 57.
229	Beehive	Unknown	32 (?)	28S	40E	MD	Lead, silver	Idle. R. 25 p. 57.
230	Black Hawk group	J. A. Darnell, Bakersfield, Calif.	28	30S	33E	MD	Lead, zinc	Idle. Herein.

231	Churchill	J. A. Foisee, Randsburg, Calif. (last known)	20	28S	40E	MD	Lead, silver	Idle. R. 25 p. 57.
232	Hummer	Unknown	30 (?)	28S	40E	MD	Silver, gold	Idle. R. 25 p. 57; B. 95 p. 135.
233	Mizpah-Montana	Mizpah-Montana Mining Co. (last known)	1, 6	30S	40E 41E	MD	Silver	Idle. R. 19 pp. 167-168; R. 25 p. 58; B. 95 p. 138.
234	Mizpah-Nevada	Mizpah-Nevada Mining Co.	1, 6	30S	40E 41E	MD	Silver	Idle. R. 19 p. 168; R. 25 p. 58; B. 95 p. 138.
235	Monarch Rand	Monarch Rand Mining Co., W. O. Walker, pres., 222 S. Thomas St., Pomona, Calif.	1, 12	30S	40E	MD	Silver, gold, tungsten	Idle. R. 25 p. 58; B. 95 pp. 138-139; R. 37 p. 576; R. 38 p. 330.
236	Rand Contact	Rand Contact Mining Co. (last known)	7, 18, 12, 13	30S 30S	40E 41E	MD MD	Silver	Idle. R. 19 p. 168; R. 25 p. 59.
237	Rattlesnake group	Mrs. J. S. Bishop, Mojave, Calif.	5	29S	38E	MD	Lead, silver, gold	Idle. R. 25 p. 59.
238	St. Lawrence Rand	Frank W. Royer, Red Mountain, Calif.	1	30S	40E	MD	Silver, gold	Idle. R. 19 p. 170; R. 25 p. 59; B. 95 p. 143.
239	Summit group	Pacific Mines Corp., Los Angeles, Calif. (last known)	15	26S	33E	MD	Lead, silver	Idle. R. 25 p. 59.
240	Treasure Hill	Treasure Hill Mining Co., Bakersfield, Calif. (last known)	1	30S	40E	MD	Silver, gold	Idle. R. 19 pp. 170-171; R. 25 p. 60; B. 95 pp. 143-144.
241	White Horse	White Horse Rand Mining Co., Selma, Calif. (last known)	1	30S	40E	MD	Silver	Idle. R. 19 p. 171; R. 25 p. 60; R. 29 p. 276; B. 95 p. 144.
242	Cuddeback cinnabar mine	Cuddeback Cinnabar Corp., C. D. Cuddeback pres., Tehachapi, Calif.	27	31S	32E	MD	Quicksilver	Idle. R. 17 p. 314; R. 25 pp. 60-61; B. 78 p. 47; R. 35 pp. 380-382; Min. Sci. Press, vol. 114 p. 79.
243	Hogan-Mallery (Meek-Hogan)	Tejon Ranch Co., Brodie Hamilton, pres., 202 W. 1st St., Los Angeles, Calif.	25	9N	18W	SB	Tin	Idle. Herein; "Strategic Minerals Investigations" U. S. Geol. Survey.
244	Bald Eagle	Unknown	31	26S	34E	MD	Tungsten	R. 38 p. 327.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
245	Bald Mountain	Unknown	14	27S	32E	MD	Tungsten	Idle. R. 17 p. 315; R. 25 p. 62; R. 38 p. 327.
246	Basin View	M. J. Gusty and C. G. Steadfield, 1314 N. Highland Ave., Los Angeles, Calif.	31 (?)	29S	33E	MD	Tungsten	Idle. Herein.
247	Big Lode	Eliza Coughran, Mary Canfield	32	26S	34E	MD	Tungsten	R. 38 p. 327.
248	Big Tungsten	J. Kreta, Randsburg, Calif.	3	30S	40E	MD	Tungsten	Idle. R. 38 p. 330.
249	Blue Point	Frank Feldman	10, 11, 14, 15	30S	31E	MD	Tungsten	Idle. R. 37 p. 312; R. 38 p. 330.
250	Buckhorn (Why Not)	J. R. Rogers (last known)	19	25S	32E	MD	Tungsten	Idle. R. 37 p. 305; R. 38 p. 325; U. S. Geol. Survey Bull. 725 p. 264.
251	Cadillac	O. G. Wood, Glennville, Calif.	7, 8	25S	32E	MD	Tungsten	Idle. R. 38 p. 325; R. 37 pp. 300-301; U. S. Geol. Survey Bull. 725, 1922.
252	Consolidated Mines	(See also under Gold)	35	29S	40E	MD	Tungsten	Idle. B. 95 p. 132; Tungsten: The Mineral Industry During 1915, vol. 24 p. 688; same for 1925 p. 702.
253	Cow Canyon	A. N. Houser, Weldon, Calif., W. P. Lewis, Trona, Calif.	12 (?)	25S	36E	MD	Tungsten	Idle. R. 39 p. 121.
254	Donlevy (Orrell group)	Lee Orrell, Weldon, Calif.	14	29S	34E	MD	Tungsten	Idle. R. 38 p. 329; R. 39 p. 62; herein.
255	El Diablo (Trojan)	El Diablo Mining Co., Bishop, Calif.	31	25S	33E	MD	Tungsten	Idle. Reported by El Diablo Mining Co.

256	Fidgie group	J. C. Cuddeback, H. F. Liebel and Wiley C. Dorris, Tehachapi, Calif.	23	27S	33E	MD	Tungsten	Idle. R. 38 p. 328.
257	F.O.B.	Grant P. Merrill, Mojave, Calif., A. L. Browthers, Bishop, Calif.	1 (?)	26S	37E	MD	Tungsten	Idle. R. 39 p. 121.
258	Four K group	H. J. Kutzner, Havilah, Calif.	26	27S	32E	MD	Tungsten	Idle. R. 37 p. 575; R. 38 p. 327.
259	General MacArthur group	L. M. Allen, 609 Alexander St., San Fernando, Calif.	2	10N	15W	SB	Tungsten	Idle. R. 37 p. 575; R. 38 p. 332.
260	Gold Wash (Ben Hur)	Edw. Herkelrath, Randsburg, Calif.	1	30S	40E	MD	Tungsten	Idle. R. 27 p. 342; R. 38 p. 330; B. 95, p. 129.
261	Gribble group	Fred L. Gribble, Bakersfield, Calif.	19	25S	32E	MD	Tungsten	Idle. R. 39 p. 63.
	Gwynne and Jennette (see 102 under Gold)	Otto and Jack Geringer, Mojave, Calif.	21, 22	29S	34E	MD	Tungsten, gold	Idle. R. 29 p. 307; R. 37 p. 575; R. 38 p. 329.
262	Herschel Kelso	R. A. Brown, A. M. Kidd, M. W. Pollock, Geo. S. Seib (last known)	17	25S	32E	MD	Tungsten	Idle. R. 37 p. 302; R. 38 p. 325; U. S. Geol. Survey Bull. 725.
263	Hi Peak	James Hoyt, Beverly Hills, Mrs. C. C. Parma, Pasadena, Calif.	10, 15	26S	38E	MD	Tungsten	Idle. R. 38 p. 327; R. 39 pp. 121-122; herein.
264	High Power	Patten, Peyton, Higgins, Ellis, McCornell	20	25S	32E	MD	Tungsten	Idle. R. 38 p. 325 (D. M. Lemmon).
265	Howe group	J. C. Howe, Havilah, Calif. (last known)	23	27S	32E	MD	Tungsten	Idle. R. 17 p. 315; R. 38 p. 327.
266	Ideal	J. C. Rook, Glennville, Calif.	20, 21	25S	31E	MD	Tungsten	Idle. R. 37 p. 576; R. 38 p. 325.
267	King (Sierra, Herschel, Owl, Ideal)	Various	17, 20	25S	32E	MD	Tungsten	Idle. R. 38 p. 325; U. S. Geol. Survey Bull. 725.
268	Little Dick and Good Hope	C. W. Pascoe, Kernville, Calif.	23	25S	33E	MD	Tungsten	Idle. R. 36 p. 332; pp. 343-378; R. 37 p. 301; R. 38 p. 326.
269	Little Wonder	J. E. Ramey, et al.	33	28S	32E	MD	Tungsten	Idle. R. 38 p. 329.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
	Locarno-Simon group (see 138, Locarno, under Gold)							Idle.
270	Major (Rand, Ione, and Sweet)	Brooke Woods, Glennville, Calif.	19, 20	25S	32E	MD	Tungsten	Idle. R. 37 pp. 302-303; R. 38 p. 325; U. S. Geol. Survey Bull 725, p. 263.
	Minnehaha (see 149 under Gold)						Tungsten	
271	Mintern	C. C. Mintern, C. G. Pasley	24	25S	33E	MD	Tungsten	Idle. R. 37 p. 576; R. 38 p. 326.
272	Miranda	Theodore Miranda, Isabella, Calif.	1	26S	33E	MD	Tungsten	Idle. R. 36 pp. 332-333, pl. II.
	Monarch Rand (see 235 under Silver)		1, 12	30S	40E	MD	Tungsten	
273	Mountain View	Geo. Ramey and H. D. Hicks, Bodfish, Calif.	26	28S	32E	MD	Tungsten	Idle. R. 36 p. 577; R. 38 p. 328.
274	Naja	H. Buttebred and L. V. Stover	1	29S	33E	MD	Tungsten	Idle. R. 38 p. 329; R. 39 p. 64.
275	Owl	Brook Woods, Glennville, Calif.	17	25S	32E	MD	Tungsten	Idle. R. 37 p. 577; R. 38 p. 325; U. S. Geol. Survey Bull. 725.
	Pine Tree (see 165 under Gold)						Tungsten	
276	Plasse	A. H. Plasse	12	27S	34E	MD	Tungsten	Idle. R. 38 p. 328.
277	Play Boy	Don Hennings	1	26S	33E	MD	Tungsten	R. 38 p. 327.
278	Prosperity	A. O. Zuck and W. R. Tillman, Havilah, Calif.	35	27S	32E	MD	Tungsten	Idle. R. 36 p. 333; R. 38 p. 328.
279	Pyarin group (Indian Wells)	Warner, Merrill, Crowthers	1	26S	37E	MD	Tungsten	R. 38 p. 327.

280	Radcliffe		12	30S	40E	MD	Tungsten	Idle. R. 17 p. 316; R. 25 p. 63; R. 38 p. 331.
281	Royal Bohee (Royal Boyn)	A. M. Powell, Randsburg, Calif.	9	30S	40E	MD	Tungsten	Idle. R. 17 p. 316; R. 37 pp. 289-290.
282	Sierra	Bill Zellner, Glennville, Calif.	20	25S	32E	MD	Tungsten	Idle. R. 38 p. 325; U. S. Geol. Survey Bull. 725.
	Stanford (see 193 under Gold)						Tungsten	
283	Star Dust and Black Cat	Dorris and Cuddeback, Tehachapi, Calif.	1	27S	34E	MD	Tungsten	Idle. R. 38 p. 328; R. 39 p. 62.
284	Summit Lime Company	Summit Lime Company, Whittier, Calif.		11N 12N	15W	SB	Tungsten	Idle. R. 37 p. 578; R. 38 p. 332; R. 39 p. 62.
285	Sunset group (Hawk mine)	M. J. Lovett, W. M. Price, Randsburg, Calif.	6	30S	40E	MD	Tungsten	Idle. R. 17 p. 316; R. 37 p. 313.
286	Syrus Canyon group	C. W. Pascoe, Kernville, Calif.	35	25S	33E	MD	Tungsten	Idle. R. 36 p. 333.
287	Top of the World (see 9)	H. G. Hubbard et al.	34	30S	32E	MD	Tungsten	Idle. R. 38 p. 330; R. 39 pp. 61-62.
288	Tungsten Big Lode	H. W. Daley and Geo. Munson, Isabella, Calif. (last known)	11, 14	27S	34E	MD	Tungsten	Idle. R. 36 p. 578; R. 38 p. 328; R. 39 p. 64.
289	Tungsten Chief (Wall Street group, Ophir-Zuck)	T. J. McKee and N. T. McKee, Caliente, Calif.	26, 27, 33	28S	32E	MD	Tungsten	Idle. R. 17 p. 316; R. 37 pp. 304, 578.
290	Tungsten Hill	T. M. Smith and E. E. Lambert, Havilah, Calif.	3	28S	32E	MD	Tungsten	Idle. R. 37 p. 579; R. 38 p. 328; R. 39 p. 122.
291	Tungsten King	A. O. Zuck and W. R. Tillman, Havilah, Calif.	26	27S	32E	MD	Tungsten	Idle. R. 17 pp. 315-316; R. 25 p. 62; R. 37 p. 303; R. 38 p. 328.
292	Tungstore mine No. 2	Tungstore Mines Co.	11	25S	29E	MD	Tungsten	Idle. R. 38 p. 325; (D. M. Lemmon).

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Metals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
293	Tungsten Queen	Mintern Estate, Bakersfield, Calif.	30, 31	25S	33E	MD	Tungsten	Idle. R. 37 p. 579; R. 38 p. 326.
294	Williams Ranch	Nick Williams, Caliente, Calif.	16	29S	33E	MD	Tungsten	Idle. R. 37 p. 579; R. 38 p. 329.
295	Yellow Aster (see under Gold)						Tungsten	Idle. R. 14 p. 514; R. 37 p. 281; B. 95 p. 121.
296	Tejon Ranch (Cully and Hoyes, Kelso)	Tejon Ranch Co., Brodie Hamilton, pres., 202 W. First St., Los Angeles, Calif.	35(?)	9N	18W	SB	Zinc	R. 39 p. 65.

Nonmetals

Number	Name of mine	Owner (name and address)	Sec.	T.	R.	B & M	Mineral product	Remarks and references*
297	San Emigdio asbestos	R. C. Cuddy, Frazier Park, Calif.	32(?)	9N	21W	MD	Asbestos	Idle. R. 25 p. 63.
298	Pacific Coast borax	Pacific Coast Borax Co., 510 W. Sixth St., Los Angeles, Calif.	app. 4500 acres	11N	8W	SB	Borax	R. 25 pp. 77-79; R. 13 pp. 325-278; U. S. Geol. Survey Bull. 785c; Prof. Paper 158i.
298A	Sukow borax (see Pacific Coast Borax, 298)		14	11N	8W	SB		R. 25 pp. 79-80.
298B	Western borax mine (Part of Pacific Coast Borax mine, 298)	Pacific Coast Borax Co., 510 W. Sixth St., Los Angeles, Calif.	S½ 24	11N	8W	SB	Borax	R. 25 p. 80.
299	Amargo bentonite deposit	John Kennedy, 2550 E. Olympic Blvd., Los Angeles, Calif.	26	11N	8W	SB	Clay	Herein.
300	Iron Canyon bentonite	Mrs. J. S. Bishop, Mojave, Calif.	19(?)	29S	38E	MD	Bentonite	Idle. R. 25 p. 67.

301	Antelope Materials Co.	Macco Construction Co., 815 Paramount Blvd., Clearwater, Calif.	30, 32	9N	10W	SB	Clay	Herein.
302	California fullers earth	C. Weighelt, Bakersfield, Calif.	14	27S	28E	MD	Clay	Idle. R. 14 pp. 480-481; R. 25 pp. 65-66; B. 38, pp. 274-275.
303	Duran bentonite deposit	J. R. Duran, Randsburg, Calif.	21(?)	28S	40E	MD	Bentonite	Idle. R. 25 p. 66.
304	Filtrcl clay	Filtrol Corp., 634 S. Spring St., Los Angeles, Calif.	2, 34	32S 31S	34E 34E	MD MD	Clay	Idle. R. 25 pp. 66-67; herein.
305	Jawbone Canyon clay (Williams)	American Mineral Co., 5601 S. Boyle Ave., Los Angeles, Calif.	27, 34	30S	36E	MD	Clay	R. 25 p. 65; herein.
306	Koehn clay	Chas. Koehn, Gypsite, Calif.	28(?)	29S	38E	MD	Clay	Idle. R. 25 p. 67.
307	McKinney clay	Chas. McKinney, Saltdale, Calif.	28(?)	29S	38E	MD	Clay	Idle. R. 25 p. 67.
308	Muroc clay	Sierra Talc and Clay Co., 5509 Randolph St., Los Angeles, Calif.	2, 3	11N	9W	SB	Clay	Idle. R. 25 pp. 67-68.
309	Muroc silt deposit	Mojave Corp., 1074 W. Los Nietos Rd., Los Angeles, Calif.	21, 22, 23	10N	9W	SB	Clay	R. 25 p. 64; herein.
310	Riley clay	Southern Pacific Railroad, leased to O. L. Riley Co., 1665 N. Ventura Ave., Ventura, Calif.	19	9N	11W	SB	Clay	Herein.
311	Rosamond clay	H. E. Titus, Rosamond, Calif.	11	9N	13W	SB	Clay	Idle. R. 25 p. 64; B. 99 pp. 89-90.
312	Webb clay	W. S. Webb, Rosamond, Calif.	NW¼ 10	9N	13W	SB	Clay	Idle. R. 25 pp. 64-65; B. 99, p. 90.
313	Snow White clay	O. J. Salisbury, Cantil, Calif.	30	29S	32E	MD	Clay	Idle. R. 25 p. 68.
314	Stevens clay	William Stevens, Cantil, Calif.	9(?)	29S	38E	MD	Clay	Idle. R. 25 p. 68.
315	White Bluff clay	----------	18	29S	38E	MD	Clay	Idle. R. 25 p. 68.
316	White Swan clay	Ray Young and Frank Miller, Mojave, Calif.	14	30S	36E	MD	Clay	Idle. R. 25 p. 68.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Tabulated list of mines in Kern County—Continued

Nonmetals

Number	Name of mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B & M		
317	White Ridge dolomite	Florence Cuddy, Frazier Park, Calif.	25	9N	20W	SB	Dolomite	Idle
318	Rosamond feldspar (Townsend)	N. W. Sweetzer, Rosamond, Calif.	SW¼ 6	9N	12W	SB	Feldspar, silica	R. 25 p. 65; U. S. Bur. Mines, Inf. Circ. 6931, 1937; Herein.
319	Cottonwood Creek gypsum	Oscar Rudnick, Trustee and P. Sumner Brown, Bakersfield, Calif.	21, 27, 28, 29	29S	30E	MD	Gypsum	Idle. R. 25 p. 69; Heerin.
319A	Crystal Gypsum Company	Crystal Gypsum Co., P. O. Box 823, Oildale, Calif.	27, 34 35	32S	27E	MD	Gypsum	Herein.
320	Holloway gypsum	H. M. Holloway, Inc., Box 310, Lost Hills, Calif. (leasor)	3, 10, 11, 13, 14, 15, 24	26S	20E	MD	Gypsum	Herein.
321	Monolith gypsum	Monolith Portland Cement Co., 215 W. Seventh St., Los Angeles, Calif.	31	30S	22E	MD	Gypsum	Idle. R. 25 p. 69; herein.
322	Mojave Desert gypsum	Mojave Desert Agricultural gypsum, Lancaster, Calif.	28	30S	38E	MD	Gypsum	R. 25 p. 69; herein.
322A	Pacific Gypsum Company	W. D. Fowler, 230 Columbus St., Bakersfield, Calif.	26	32S	27E	MD	Gypsum	Herein.
323	Antelope Valley marble	Southern California Marble Co., San Francisco, Calif. (last known)	2	9N	17W	SB	Marble	Idle. R. 6 pt. 1, p. 13; R. 13 p. 629; R. 14 p. 520; R. 25 p. 73; B. 38 p. 100.
324	Cuddy Canyon limestone	Henry Kramer, La Crescenta, Calif.	(?)	9N	20W	SB	Limestone	Idle. R. 25 p. 70.
325	Erskine Creek		(?)	27S	33E	MD	Limestone	Idle. R. 25 p. 70.

326	Isabella limestone			26S 27S	33E 34E	MD	Limestone	Idle. R. 25 p. 70.
327	Monolith Portland Cement Co.	Monolith Portland Cement Co., A. G. Bartlett Bldg., Los Angeles, Calif.	14	32S	33E	MD	Limestone, cement	R. 25 pp. 70-72; herein.
328	Summit limestone (see 284)	Summit Lime Company, Whittier, Calif.		11N 12N	15W	SB	Limestone	Idle. R. 25 p. 72.
329	Union lime	Union Lime Company	1720 acres	12N	15W	SB	Limestone	Idle. R. 13 p. 628; R. 14 pp. 518-519.
330	Bissell magnesite		11	10N	10W	SB	Magnesite	Idle. R. 17 pp. 312-313; R. 14 pp. 519-520; R. 25 p. 73 U. S. G. S. B. 540 pp. 512-516.
331	Black Eagle and Gray Eagle	R. L. Meuer and Della Gerbracht, Randsburg, Calif.	4	29S	38E	MD	Perlite	Herein.
332	Black Mountain pumice	R. L. Meuer and Della Gerbracht, Randsburg, Calif.	32	29S	38E	MD	Pumice	Herein.
333	Calsilco deposit (Holly Cleanser)	Calsilco Corp., 445 S. Amalia, Los Angeles; leased to Insulpum Corp., Los Angeles, Calif.	33, 4	28S 29S	38E 38E	MD	Volcanic ash	R. 25 p. 76; herein.
334	Cudahy silica (Dutch Cleanser)	Cudahy Packing Co., Los Angeles, Calif.	7	29S	38E	MD	Volcanic ash	Idle. R. 25 p. 76; herein.
335	Opal pumice	R. L. Meuer and Della Gerbracht, Randsburg, Calif.	4	29S	39E	MD	Pumice	Idle. Herein.
336	Parrott and Allec silica	William Parrott and Allec, Cantil, Calif.	30(?)	29S	38E	MD	Volcanic ash	R. 25 p. 76; herein.
337	White Castle pumicite	F. D. Shuck, Glendora, Calif.	32	28S	39E	MD	Pumicite	Idle. Herein.
339	Long Beach Salt Company	Long Beach Salt Company	1, 11	30S	38E	MD	Salt	R. 25 p. 81; herein.
338	Williams pumicite deposit	Tom Williams, Randsburg, Calif.	32	28S	39E	MD	Pumicite	Idle. Herein.

---

* R. = Report; B = Bulletin; R.M. = Register of Mines; P.R. = Preliminary Report published by California State Division of Mines.

Oil and Gas

Introduction

Location of Oil and Gas Fields

Kern County is one of the largest inland counties in California, extending broadly in a west to east direction from the crest of the Temblor Range in the southern Coast Ranges across the southern portion of the San Joaquin Valley and the northern foothills of the Tehachapi Mountains and across the southern Sierra Nevada Mountains to the Mojave Desert. The irregular western boundary of the county rather closely approaches the trace of the San Andreas fault zone. The oil and gas fields are found entirely within the San Joaquin Valley and bordering foothills within the limits of the Tertiary and early Quaternary sedimentary basin.[17]

Acknowledgment

Information used in this report has come from a wide variety of sources, but particular acknowledgment is made to the California Division of Oil and Gas, R. D. Bush, Supervisor, for statistical data and to E. Huguenin, Chief Deputy, for reading the manuscript.

Kern County Mineral Production

Kern County has had the largest value of mineral production among California counties each year for the past several years, running just ahead of Los Angeles in that respect. Each of the two counties produces more than double the value of mineral products of third-ranking Fresno County. A breakdown of the value of Kern County mineral production for the last year for which published statistics are available may be found in the accompanying table. It may be readily computed that more than 90 percent of the value of Kern County mineral production is in oil and gas. Kern County now leads Los Angeles County in annual value of those commodities. Total Kern County production of crude oil in 1947 was 103,743,760 barrels, a daily average of 284,229 barrels; in the same year comparable figures for Los Angeles County were 92,992,724 barrels and 254,775 barrels, respectively.[18]

*Value of mineral production in Kern County in 1946**

Product	*Value*
Clay	$ 544,841
Gold	94,710
Gypsum	352,484
Natural gas	5,694,426
Petroleum	120,353,402
Silver	6,972
Stone	327,259
Unapportioned	5,708,558
Total value	$133,082,652

* Averill, C. V., King, C. R., Symons, Henry H., and Davis, F. F., California mineral production for 1946: California Div. Mines Bull. 139, p. 119, 1948.

---

[17] For a more complete discussion of the location of oil fields in relation to basic geographic and geologic factors, refer to Jenkins, Olaf P., Geomorphic provinces of California: California Div. Mines Bull. 118, pp. 83-88, 1943; and to Reed, Ralph D., Position of the California oil fields as related to geologic structure: California Div. Mines Bull. 118, pp. 94-97, 1943.

[18] Annual review, Petroleum World, pp. 202-205, 1948.

In 1946 Kern County produced a total of 100,604,856 [19] barrels of oil and 37,034,330 [20] thousand cubic feet of gas, while the state totals were 317,231,926 barrels of oil and 363,630,070 thousand cubic feet of gas for the same period. Thus, Kern County produced nearly one third of the oil produced in California, leading California counties. California produces approximately 18 percent of the oil produced in the United States. Kern County gas production ranked it sixth among California counties in 1946.

Reserves of Oil and Gas

Kern County has large reserves of oil and gas as indicated in the accompanying tables compiled from Petroleum World.[21] The total of liquid hydrocarbon reserves is shown, as of January 1, 1948, to be 1,548,822 thousand barrels for Kern County, as compared with a California total of 3,607,114 [22] thousand barrels. Thus, Kern County has approximately 43 percent of the petroleum reserves of California.

The Division of Oil and Gas [23] reports Kern County gas reserves as of July 1, 1947 (including Trico Tulare County production) as 3,108,673,340 thousand cubic feet, as compared with a California total of 11,981,748,261 thousand cubic feet. Kern County ranks sixth among California counties in gas production and has approximately 26 percent of the gas reserves of the state.

Wardner [24] reports seven California oil fields have reserves exceeding 100,000,000 barrels of oil each, as of January 1, 1948. Two of these, Midway-Sunset and Elk Hills, are in Kern County; the latter is now largely shut in as a Naval Reserve.

Estimated petroleum reserves of Kern County *

Total of all Kern County liquid hydrocarbon reserves as of January 1, 1948, were 1,548,822 thousand barrels.

Liquid hydrocarbon reserves of 10 largest fields of Kern County, in thousands of barrels, were, as of January 1, 1948:

Elk Hills	450,000
Midway-Sunset	173,062
Buena Vista	133,044
McKittrick-Cymric	114,229
Coles Levee, North	98,884
Rio Bravo	54,020
Mount Poso	53,395
Greeley	47,702
Kern River	45,219
Kern Front	39,534

* Data from Annual Review, Petroleum World, pp. 68-69, 1948.

---

[19] Summary of Operations, California oil fields, California Div. Oil and Gas, p. 32, Jan.-June 1947.

[20] Summary of operations, California oil fields, California Div. Oil and Gas, p. 32, Jan.-June 1947.

[21] Annual Review, Petroleum World, pp. 68-69, 1948.

[22] Reports on proved reserves of crude oil, natural gas liquids, and natural gas, vol. 2, Am. Petroleum Inst., December 31, 1947.

[23] Summary of operations, California oil fields: California Div. Oil and Gas, pp. 28-30, Jan.-June 1947.

[24] Wardner, Wm. R. Jr., Petroleum development and production in California in 1947, Statistics of oil and gas development and production: Am. Inst. Min. Eng., Petroleum Div., p. 40, 1948.

*Current production and estimated ultimate production of major oil fields in Kern County **

The Oil and Gas Journal lists 28 oil fields in California which are estimated to have reserves of at least 100 million barrels each. Nine such fields are in Kern County.

Field	*Year of discovery*	*Production in thousands of barrels* *First half 1948*	*Cumulative to 7/1/48*	*Estimated ultimate*
Midway-Sunset	1901	7,725	728,584	825,000
Elk Hills	1919	1,176	198,141	470,000
Buena Vista	1909	8,358	355,762	440,000
Kern River	1899	2,207	299,988	335,000
McKittrick-Cymric	1887	3,939	111,489	153,000
Mount Poso	1926	2,369	98,254	151,000
Coles Levee, North	1938	2,959	40,408	112,000
Kern Front	1925	1,668	66,134	103,000
Rio Bravo	1937	2,214	45,114	100,000

* Data from Mid-year report, Oil and Gas Jour., pp. 183-184, July 29, 1948.

*Estimated natural-gas reserves of Kern County **

Total of all Kern County natural-gas reserves as of July 1, 1947, was 3,108,673,340 ** thousand cubic feet.

Dry-gas fields	*Thousands of cubic feet*
Trico	221,200,882**
Bowerbank	34,347,870
Semitropic	11,742,145
Buttonwillow	587,129
Ten largest gas-producing oil fields	
Paloma	638,294,988
Elk Hills	589,374,508
Coles Levee, South	560,057,466
Coles Levee, North	364,820,839
Rio Bravo	153,732,812
Greeley	118,333,098
Ten Section	105,379,768
Midway-Sunset	98,140,019
Belridge, North (R-Zone)	65,628,657
Canal	37,400,928

* Data from Summary of Operations, California oil fields, p. 29, California Div. Oil and Gas, Jan.-June 1947.

** Includes Trico production in Tulare County.

Recent General Developments

General developments in 1947 and early 1948 in Kern County were along the same lines as throughout the oil-producing areas of the state. They were principally: (1) A record of high production reflecting the high prices for crude and large post-war demand; (2) an accelerated exploration and drilling program; (3) some extensions to fields, new pools, and small new fields, but no major discovery; (4) additions to reserves, not enough to replace withdrawal; (5) wider use of gas injection to maintain pressures, and (6) considerable progress in unitization plans of development of pools and fields.

Geologic Occurrence[25]

The oil fields of Kern County show accumulation of oil under a considerable variety of structural and stratigraphic conditions. These are referred to briefly for each field in the section on *Development and Production Since 1940* to follow.

The importance of detailed, complete geological study, not only during exploration for well location, but particularly during development, is now generally recognized. Better than half the additions to reserves in the past few years have been made in old fields as a result of subsurface geology. Exploration in California has been increasingly successful since the 1940 low of only one discovery during the year. Nine new oil and gas fields and 32 new oil and gas pools were discovered in California in 1947. Two of the new fields and 15 of the new pools were in Kern County. Successful exploration in Kern County has come about, first, in the early 1940's through seismographic surveys, and secondly, since 1945, almost entirely through subsurface geology. It is likely that future discoveries will come through extensive exploration by surface geology in new areas and intensive application of subsurface geology in proximity to known fields.

Devolpment and Production Since 1940

East Side Fields

Jasmine Area. The Jasmine area was discovered in 1946 by Pacific Oil and Gas Development Corporation well Cantleberry 72 after years of intensive prospecting by various companies. The discovery well produced 76 barrels per day of about 15-degree gravity oil from 30 feet of Lower Vedder sand encountered at a depth of 2,770 feet. By the end of 1947 the company had five wells producing 190 barrels per day. Slow development of the field was partly due to water shut-off problems. The structure is anticlinal.

In 1948 Continental Oil Company discovered production in the Stevens sand in the San Emidio area west of Wheeler Ridge.

Mount Poso. Relatively shallow wells, averaging about 1,600 feet have produced from Vedder sands in a faulted homoclinal structure, since discovery of the main Mount Poso field in 1926. A comparatively steady but unspectacular development has taken place in the past few years, and the field now ranks seventh among Kern County fields in oil reserves.

---

[25] For complete accounts of the basic geology and detailed geology of Kern County oil fields see Geology of California and the occurrence of oil and gas: California Div. Mines Bull. 118, pp. 81-277, 1943, and Descriptions of individual oil and gas fields, San Joaquin Valley and bordering foothills: California Div. Mines Bull. 118, pp. 482-583, 1943.

Major structural control of oil accumulation in Kern County fields.

Domes and normal closed anticlines; faulting and unconformities of little or no importance	Antelope Hills Bacon Hills (?) Bowerbank gas Buttonwillow gas Canal Canfield Ranch East Strand Greeley Jasmine Lost Hills McDonald Anticline North Belridge Paloma Republican and Spellacy anticlines of Midway Rio Bravo Semitropic gas Strand Ten Section Trico gas Wasco Wheeler Ridge
Anticlines with faulting important	Coal Canyon (?) Coles Levee, North Coles Levee, South Devils Den Elk Hills Fruitvale Kern Bluff McKittrick-Cymric Salt Creek Tejon Tejon Hills Temblor
Anticlines with overlaps or unconformities important	Buena Vista Hills Elk Hills North Belridge
Sand lenses along homocline	Kern River
Unconformities; anticlines less important	Edison Gibson area of Midway North Midway
Faults	Comanche Point (?) Kern Front Mountain View Mt. Poso Poso Creek (?) Round Mountain

*Geologic formation and zone names used in this report.**

Subsurface zones and formations	Geologic formation to which zone is equivalent in part or in whole	Geologic age of zone
Tulare formation	Tulare	Pleistocene
San Joaquin clay formation	San Joaquin	Upper Pleistocene
Kern River formation	Kern River	Pleistocene to lower Pliocene
Upper Duff	Kern River	Pleistocene to lower Pliocene
Scalez	San Joaquin	Upper Pliocene
Etchegoin formation	Etchegoin	Lower Pliocene
Transition	Chanac-Santa Margarita	Lower Pliocene-upper Miocene
Wharton sand	Santa Margarita	Upper Miocene
Chanac formation	McLure-Reef Ridge-lower Etchegoin	Lower Pliocene-upper Miocene
Stevens sand	Santa Margarita	Upper Miocene
Reef Ridge formation	Reef Ridge	Upper Miocene
McLure shale	McLure	Upper Miocene
Maricopa formation	Maricopa	Upper Miocene
Santa Margarita formation	Santa Margarita	Upper Miocene
Carneros formation	Temblor	Middle Miocene
Button Bed	Temblor	Middle Miocene
Temblor formation	Temblor	Middle Miocene
Olcese sand (lower, middle and upper Olcese)	Temblor	Middle Miocene
Lower Duff-Olcese	Temblor	Middle Miocene
Elbe sand-lowest Jewett	Vaqueros	Lower Miocene
Jewett silt	Vaqueros	Lower Miocene
Vedder sand (lower and upper Vedder)	Vaqueros	Lower Miocene
Rio Bravo sand	Vaqueros	Lower Miocene
Phacoides	Vaqueros	Lower Miocene
Hannah	Vaqueros	Lower Miocene
Santos shale	Vaqueros	Lower Miocene
Vaqueros formation	Vaqueros	Lower Miocene
Tumey shale	Tumey	Oligocene
Oceanic sand	Tumey-Kreyenhagen	Lower Oligocene-upper Eocene
Wagon Wheel formation	Tumey	Oligocene
Kreyenhagen formation	Kreyenhagen	Upper Eocene
Point of Rocks formation	Point of Rocks	Upper Eocene
Schist	Basement complex	Pre-Upper Jurassic

---

* Simplified and modified from Goudkoff, Paul P., Correlation of oil field formations on west side of San Joaquin Valley: California Div. Mines Bull. 118, pp. 247-252, 1943; and Ferguson, Glenn C., Correlation of oil field formations on east side San Joaquin Valley: California Div. Mines Bull. 118, pp. 239-246.

Poso Creek. The Poso Creek field, lying just west and on the valley side from Mount Poso, has obtained production mainly from the nonmarine Chanac formation at depths of 1,200 to 3,500 feet. The discovery well in the Premier field was drilled 1929; the Enas field (1943), Premier East (1944) and Premier West (1946) represent new fields in the Poso Creek group discovered since 1940. First well in the Enas field yielded 164 barrels per day from the Chanac horizon; the East Premier discovery yielded 143 barrels per day, also from the Chanac. Eighty acres of the latter field were proven by the end of 1944. The Premier West discovery by Bender Oil Operations at well Kelly 2 was of importance, as it marked the first Poso Creek discovery in the Santa Margarita formation. However, production proved disappointing, as the well soon declined from an initial 130 to only 5 barrels per day.

Round Mountain. Round Mountain, discovered in 1927, has produced from the Vedder, Elbe, and Jewett zones. The oil is trapped in a complexly faulted monocline. The Sharktooth area was discovered in 1943 by a 180 barrel per day well. In 1947 the Alma-Vedder field was discovered by Morton and Kohlbush (now Barnsdall Oil Company) Alma 1 in sec. 15, T. 28 S., R. 28 E., M.D., which produced an initial 152 barrels per day of 12-degree gravity oil from a fault accumulation in Vedder sand about half a mile west of the Sharktooth area. Three other successful completions were made in 1947 from the same zone.

Kern River. The very shallow production of the Kern River field was discovered in 1899 by a pick and shovel well at a depth of 50 feet. Production has come from lenticular sands along a gently dipping homoclinal structure, and entirely from the continental Kern River series. Two deep tests by Tide Water Associated in 1946 penetrated barren Olcese, Vedder, and Eocene sands, ending in basement granitic rock. The basement was encountered at 6,145 feet. There seems little prospect that any production will be obtained below the Kern River beds. However, the field has been a large producer and is ranked ninth among Kern County fields in oil reserves. A number of 1948 completions, all small, have notably increased production in the last few months. Kern River, with 108 producing wells completed in 1947, was the most active field in Kern County for that year. The west and southwest borders of the field were extended about a quarter of a mile.

Kern Front. Production in the Kern Front field has come from three horizons in the Chanac sands. The structure is a faulted homocline dipping southwest; the wells average about 2,000 feet in depth. Development since discovery in 1925 has been active and at present the Kern Front field has estimated reserves of more than 39,000,000 barrels, and ranks tenth among Kern County fields in this respect. The field ranked fifth among the most active in the county in 1947 and sixth in 1946.

Kern Bluff Area. Oceanic Oil Company discovered new production in the Kern Bluff area in 1947 in sec. 7, T. 29 S., R. 29 E., M.D., through their Needham-Bloemer 15 well. The well showed an initial production of 79 barrels per day from an oil sand between 815 and 935 feet in depth. By the end of the year 1947 there were six wells producing a total of 300 barrels per day of approximately 15-degree gravity oil from Pliocene-Miocene transition and Santa Margarita sands. The structure has been described as a faulted anticline. So far, in the first half of 1948, several good wells have been completed, notably by Vedder and Parkford, in sec. 12, T. 29 S., R. 28 E., M.D.

Fruitvale. The discovery well in the Fruitvale field was completed in 1928 on a low-relief dome on the Kern River uplift, where the accumulation was probably influenced by faulting. The Union Avenue area, just south of Bakersfield, was opened up in 1941 by Hancock Oil Company well Roberts No. 1, completed for 150 barrels per day of 14-degree gravity oil in Santa Margarita sand at a depth of 5,312 feet. Shallower production was later developed in a Chanac horizon. The location was surrounded by dry holes, none over half a mile away. The structure is monoclinal and obscured by faulting. Development of the Fruitvale field has been slow but production has been relatively steady at 2,000,000 to 3,000,000 barrels per year since 1936. Production in 1947 was down somewhat from previous years.

The Rosedale Ranch area was discovered in 1945 by General Petroleum Corporation. Both Pliocene and Miocene production have been developed and an area of about 200 acres proven productive. At the end of 1947 the area was producing about 90 barrels of oil per day.

Ant Hill. The Ant Hill field, approximately five miles north of Edison, was discovered in 1944 as a result of seismographic exploration and subsurface geology. The discovery well, Amerada S. P. 36-15, yielded 70 barrels per day of 13- to 15-degree gravity oil and was completed in the Jewett zone. Later wells were completed in the same zone and also in the higher Olcese sand. Four hundred acres had been proved by the end of 1947. Ant Hill produced more than 500,000 barrels in 1947.

Edison. Discovery well of the Edison field first produced in 1931 from the Upper Duff zone, just above the Chanac formation. Geologic occurrence of the oil is complex; structural traps include overlap of sediments, warp, westward tilt and faulting; some production is from the basement schist.

Edison has been an active field since discovery, in some years ranking among the most active fields in the state from the standpoint of number of wells drilled. Production has come chiefly from the Chanac formation, and from the Olcese sand. In 1945, however, H. H. Magee produced the first oil from fractured schist, from a 525 barrel per day well at a depth of 2,300 feet. In 1946, a total of 54 wells were completed in the schist. The limits of the area of schist production were closely determined by early 1947 and drilling in that formation had practically ceased. In 1947 most of the activity in drilling was in the *Race Track Hill* area, about 1½ miles north of Edison, discovered when British-American and Capital Company completed a 240 barrel per day well of 37-degree gravity oil in the Olcese zone.

Mountain View. First successful well in the Mountain View field was drilled in the southeast area in 1933 by Hogan Petroleum Company, producing 1,572 barrels per day of 22- to 30-degree gravity oil from a depth of 5,862 feet. The field reached its maximum production of more than 9,700,000 barrels in 1936 and has since declined, except for a considerable increase in 1947. The several geologic structures acocunting for oil accumulations are complex, and production has come from several horizons and formations, chiefly the Chanac, Transition, and Wharton zones, and, since 1946, from the schist basement.

1946 was an especially interesting and active year. Five fine wells were completed in the Transition zone, one with an initial production of 1,820 barrels per day from depths of 5,300 to 5,500 feet. In the Arvin area, good producers were obtained by deepening wells from the Upper Chanac to Lower Chanac zones. Tidewater Associated discovered production a little deeper in the Santa Margarita formation. Western Gulf Oil Company well 1 Di Giorgio in the southern part of the field opened up production in fractured schist. The well came in at 2,480 barrels per day from 5,875 to 6,163 feet, and then soon died. A well drilled by Pacific Western, P. H. Greer 53, was flowing 80 barrels per day at the end of 1947. These two wells represent the only basement production in Kern County, outside of Edison.

West Side Fields

Devils Den. The Devils Den field, discovered in 1910, includes a number of shallow wells spread over a wide area in northwestern Kern County. Production has been small, coming from the Wagonwheel and Hannah formations. Oil comes from an anticline and also from faulted homoclinal beds. The field is of minor importance. In 1944 the Etienne Lang well Occidental 30 produced 100 barrels per day of 14- to 17-degree gravity oil from the Santos sand from a depth of 1,355 feet to open up the new Blackwells Corner field southwest of Devils Den. Several wells have yielded a small total since discovery, declining somewhat in 1947.

Lost Hills. Production in the Lost Hills field comes from several horizons in the Temblor sands and the Etchegoin formation. The structure is a long, narrow, closed anticline. Maximum production of more than 4,000,000 barrels a year was reached in 1917. Production then declined over the succeeding years. In 1946 Standard Oil started a water-flooding project, using salt water under high pressure. Drilling activity along the northeast flank and north end was very greatly accelerated in 1947, resulting in increased production.

Antelope Hills. The new Antelope Hills field west of North Belridge was discovered by Shell Oil Company Williams 45-6 in 1942, which produced an initial 937 barrels per day of 17-degree gravity oil from a depth of 2,280 to 2,340 feet. Production comes from middle Miocene beds, and some from Eocene beds in a plunging anticline. Maximum production was reached in 1945 with 683,351 barrels; it has since declined slowly.

Belridge, North and South. The North and South Belridge fields have been important producers since discovery in 1911 at South Belridge, and in 1912 at North Belridge. Production comes from long, narrow, en echelon, asymmetrical anticlinal folds. Producing horizons are in the Temblor, fractured McLure and Maricopa shale, sand members near the contact of Reef Ridge shale, the Etchegoin formation, and Tulare beds. Maximum production was reached in 1945, and there has been a gradual decline since that time. Proven limits of the Tulare zone were extended in 1947 at the northwest end of the South Belridge field.

McDonald Anticline Area. Three small, shallow wells were completed in 1945 in the Phacoides zone. In 1947 the first production was obtained from the Button bed. The field appears to be of comparatively little importance.

Bacon Hills Area. One of the latest discoveries in Kern County is the Bacon Hills area where Seaboard Oil Company completed a 40 barrel per day well to a depth of 7,870 feet in the Oceanic sand. Little was known in early 1948 of the subsurface conditions and potentialities of the field, but Petroleum World[26] notes that ''Bacon Hills, on the basis of Seaboard's latest completion, looks like a good oil field.''

Temblor. Tar seeps in the region were used as early as the fifties but the present producing zone, upper Vaqueros sand, was drilled in 1900 by the Dillon 1 well. The oil is heavy and production has never been high but the field has had a remarkably long life considering that some of the present producing wells had an initial production as low as 10 barrels per day. The structure is an anticline faulted on the northwest and southwest limbs. In 1946 four shallow wells were completed on the eastern edge, averaging about 40 barrels per day from shallow depths.

McKittrick-Cymric. The region is one of the oldest in California from the standpoint of useful production of petroleum, since tar from seeps was utilized in the fifties and probably some shallow wells were dug near such seeps very early. Petroleum World[27] records the first production for the year 1898 at 10,000 barrels. Production climbed to a maximum of more than 5,800,000 barrels in 1909, declined to a low in 1933 of 651,361 barrels, and then accelerated rapidly from 1945 to date to 7,222,059 barrels for the Temblor-McKittrick-Cymric group in 1947. The rapid increase in production in the past 3 years has been largely due to the series of discoveries noted in the table below.

The most important development in the McKittrick-Cymric group in 1945 was the revival of the old Cymric field by a series of new pool discoveries. Union's completion in Upper Carneros sand on September 13 discovering the Anderson 45 pool was followed on September 18 by Standard's Weston-pool well completed in a second Carneros sand zone separated from the Anderson 45 sand by shale beds. The third pool in the Cymric series of discoveries was the Oceanic, opened by Independent Exploration Company. Union Oil completed its Anderson 54 in basal Etchegoin on December 18. Net results of the four discoveries were acceleration of exploration and the addition of important reserves to the Cymric field.

In 1946 the major development was the discovery of the new Salt Creek field which produced 2,309,349 barrels of oil in 1947.[28] Independent Exploration Company well Temblor 2 really opened up the Salt Creek development of the Carneros zone. A number of the wells drilled flowed 200 to 400 barrels per day of 17- to 20-degree gravity oil; potentials were as high as 1,000 to 2,000 barrels per day. During the year 1946, intensive development took place in the Oceanic sand of the Cymric field. The structure was determined as a northwest-striking anticline,

---

[26] Stockman, L. P., Legislative matters draw Californians to Nation's capital: Petroleum World, p. 30, March 1948.

[27] Annual review, Petroleum World, p. 206, 1948.

[28] Annual review, Petroleum World, p. 207, 1948.

New fields and new pools discovered in the McKittrick-Cymric region since 1944 *

Operator	Discovery well	Location S-T-R	Year completed	Total depth	Initial B/D Oil	Name of producing formation	Name of new field or pool
Independent Exploration	Oceanic 1	22-29S-21E	1945	4,700	956	Oceanic sand (Kreyenhagen)	Oceanic-Cymric
Standard Oil	Weston 44-26	26-29S-21E	1945	3,672	252	Carneros	Weston-Cymric
Union Oil Co.	Anderson 45-26	26-29S-21E	1945	3,610	1,094	Carneros	Anderson 45-Cymric
Union Oil Co.	Anderson 54	26-29S-21E	1945	4,070	300	Basal Etchegoin	Anderson 54-Cymric
Independent Exploration	Cymric 1	21-29S-21E	1945	4,551	----------	Etchegoin	Calitoleum-Cymric
Standard Oil	Weston 44-26	26-29S-21E	1945	3,672	----------	Lower Miocene	Weston-Cymric
Rothschild-Bender	Anderson 2	20-29S-21E	1945	4,054	(?) 720	Carneros	S. Sheep Springs
Independent Exploration	Temblor 1	17-29S-21E	1946	2,920	20	Tulare	Salt Creek
Texas Co.	West Pet 1	29-30S-22E	1946	5,173	140	Oceanic	Belgian Anticline
Independent Exploration	Temblor 2	17-29S-21E	1946	1,868	304	Carneros	Carneros-Salt Creek
Magee, H. H.	Bolton 2	22-29S-21E	1946	6,006	354	Carneros	Bolton-Cymric
Superior Oil	Woody 77	22-29S-21E	1946	1,200	58	Point of Rocks	Woody-Cymric
Standard Oil	Weston 271-27	27-29S-21E	1946	4,030	291	Phacoides	271 Sand-Cymric
Pacific Western	Midway-McKittrick A 84-30	30-30S-22E	1947	5,196	570	Point of Rocks	Eocene A-84-McKittrick
Standard Oil	73-1 Y	1-30S-21E	1947	1,734	10	Upper Miocene shale	73-1 Y-McKittrick
Superior Oil	Moore 3	16-29S-21E	1947	2,063	38	Etchegoin	Etchegoin Sheep Spring
Texas Co.	Tulare NTC One	28-30S-22E	1947	6,548	51	Point of Rocks	Eocene 28-Belgian Anticline
Independent Exploration	Roco 1	18-29S-21E	1947	1,913	197	Carneros	Roco area
Independent Exploration	Woods 1	16-29S-21E	1947	1,760	25	Pliocene	54-21 Sands Salt Creek
Rothschild-Bender	Sheep Springs 8	17-29S-21E	1947	4,904	250	Oceanic	Oceanic sand Salt Creek

---

* Data from Graham B. Moody, Am. Assoc. Petroleum Geologists Bull., p. 840, June 1946; p. 942, June 1947; pp. 880-881, June 1948.

faulted on the northeast limb and the age of the Oceanic zone was classified as between that of the Tumey shale (Oligocene) and Kreyenhagen shale (Eocene).[29] Several wells were also completed in the underlying Point of Rocks sand. The latter includes large volumes of gas. Production in the area now comes from the Tulare, Etchegoin, Carneros, Phacoides, Oceanic, and Point of Rocks beds.

In 1947-48 very active development continued in the McKittrick and Cymric fields. About half of the activity was in the Salt Creek area, but discovery and development of the Oceanic pool in Sheep Springs and development of the Tulare horizon in McKittrick front and Welport were important. Completions in the Oceanic and Point of Rocks sands represent important developments of production in the older Oligocene and Eocene sediments of the west side.

Midway-Sunset. The Midway-Sunset group has the largest reserve of any Kern County oil field with the exception of Elk Hills, which is largely shut in as a Naval Reserve. Its total production since 1900 is more than one billion barrels of oil (Buena Vista Hills included) ; 1947 was not the year of highest production, but a steady and large increase has taken place since 1941.

Most important discovery in the State of California for the year 1944 [30] was Standard Oil Company's discovery of commercial production in basal Etchegoin sand in the Buena Vista Hills. Its well 358-27B started development of the famous ''27-B'' pool with an initial output of 624 barrels per day. In 1945, the year following discovery, the pool yielded 10,861,000 barrels of oil and the proved area was extended to 4,000 acres.[31] The area was the most active in Kern County for that year, and had 140 successful completions. Western Gulf discovery of the Santiago area in sec. 21, T. 11 N., R. 23 W., S.B., in Midway-Sunset was another development of importance. Western Gulf's Woodward U. S. L. 2 developed 1,200 barrels per day of oil and 192,000 cubic feet per day of gas from Maricopa sand at a depth of 2,022 feet.

Although there were 62 successful completions during 1947 in the Midway-Sunset fields, both 1946 and 1947 production showed a considerable decline from the 1945 peak. The Pacific pool was discovered in fractured Miocene shale by General Petroleum Corporation Pacific 4 in sec. 32, T. 12 N., R. 23 W., S.B. It yielded 1,000 barrels per day of 27.5-degree clean oil, according to the Division of Oil and Gas. In early 1948, Standard discovered the new ''Sunset'' pool near Maricopa in the Sunset field. Discovery well 54-9-K in sec. 9, T. 11 N., R. 23 W., S.B., tested 60 barrels per day of 31.4-degree gravity oil from a depth of 4,985 to 5,150 feet.

Principal structures of the Midway-Sunset fields are the United and Honolulu anticlines of Buena Vista Hills, Pliocene-Miocene overlaps of North Midway, the asymmetric Midway anticline of the Republican area, the Spellacy anticline in the Williams-Twenty-Five Hills area, and the Etchegoin beds overlapping truncated Reef Ridge beds in the Gibson area.

---

[29] Summary of Operations, California Oil Fields, Div. Oil and Gas, p. 56, July-December 1946.

[30] Moody, Graham B., Developments in California in 1944: Am. Assoc. Petroleum Geologists Bull., June 1945, p. 651.

[31] Moody, G. B., op. cit.

Elk Hills. In 1912 President Taft, by executive order, created Naval Petroleum Reserve No. 1 of 38,069 acres in the Elk Hills. As a federal reserve, production has been greatly cut back except during war-time. Production statistics[32] show 281,019 barrels production in 1919, the discovery year, rapidly rising to more than 18,000,000 barrels in 1921, declining irregularly under shut-in orders to a little over 3,000,000 in 1934, rising abruptly to 15,805,271 barrels in 1945 in the closing war year, and dropping to 2,333,803 barrels in 1947. Production was cut back to about 6,000 barrels per day by early 1948. The field has the largest reserve of any Kern County oil field, variously estimated at 450 to 470 million barrels of oil.

The structure of the 43,800-acre Elk Hills field is that of a closed anticline, elongated about three times its width. Cross faulting has also locally influenced the accumulation of petroleum. The main productive zone is just below the Pliocene *Scalez* zone and is in most places from 100 to 200 feet thick; well depths are 2,000 to 8,000 feet and gravity of the oil ranges from 14 to 40 degrees. In 1941 discovery of oil in the upper Miocene Stevens sand was made. The Super-Bittium pool was discovered in 1945 when Standard Oil Company U.O.N.P.R. well 82-2B produced 338 barrels per day from a depth of 2,936 feet. Standard Oil Company opened the "24-Z" pool in Stevens sand in 1946. In 1948 the Navy Department completed an agreement with Standard Oil Company to extend exploration and development to the north and west outside of the original confines of the Reserve to fully protect Navy interests. Under this agreement Standard is given a share of the oil under its properties. The Navy Department has as its objective the prevention of outside draining of the Stevens pool. If deep test wells develop Eocene production, the Navy will probably acquire additional acreage as needed to protect that pool.

Central Valley Floor Fields

Wasco. Wasco is a relatively small, deep field which was discovered by Continental Oil Company in 1937. The discovery well produced 35 barrels per day from a depth of 9,591 feet from Maricopa chert and shale. Structure is a northwest-southeast elongated dome. The 9,591-foot horizon proved non-commercial, but the following year the "A-2" pool in Vedder sand was opened at 13,175 feet. Wasco production reached a maximum of 820,440 barrels of oil in 1944 and declined to an annual rate of about a tenth as much in early 1948.

Rio Bravo. Rio Bravo is also a deep field, which has produced from the Rio Bravo and Vedder sands at depths of more than 11,000 feet since 1937. The structure is a northwest-trending dome, about twice as long as it is wide. Rio Bravo remains a large producing field, having declined somewhat from the war-time peak of 5,919,500 barrels a year; it is among the largest of the Kern County fields from the standpoint of reserves.

Greeley. The Greeley field has had a somewhat similar history and production to the adjoining Rio Bravo field. The field was discovered in 1936 and has produced from the Stevens sand and from the Vedder sand (beginning in 1938), mainly from the latter. The structure is a northwest-striking closed anticline, about four times as long as wide. The average depth of wells in the Vedder pool is more than 11,000 feet. Greeley's estimated ultimate production is not far below that of Rio Bravo.

---

[32] Annual Review, Petroleum World, p. 206, 1948.

Strand. Strand oil field (West Strand) was discovered in 1939 as a result of seismograph surveys. Production of an average 34-degree gravity oil comes from two horizons in the Stevens sand at depths of more than 8,000 feet. The structure is anticlinal. In 1942 Tide Water Associated Oil Company KCL 56-8 was brought in at 1,000 barrels per day of 31-degree gravity oil from Stevens sand in a separate East Strand structure. The Strand field is one of the smaller producing fields of Kern County.

Canal. The Canal field is another of the smaller fields of Kern County. Production comes from the upper Stevens sand from a dome with small closure and a slight east-west elongation. The field was discovered in 1937 and has been completely developed according to pattern. Annual production is now at a rate of about one-third that of the 1940 maximum.

Coles Levee, North. The North Coles Levee field was discovered by Richfield Oil Corporation in 1938, the discovery well producing 3,752 barrels per day of 48-degree gravity oil from a depth of 9,150 feet. The structure is a faulted anticline. Subsequent new-pool discoveries in 1939, 1941, 1946, and 1947 have maintained annual production at close to 6,000,000 barrels. North Coles Levee is rated fifth in Kern County with respect to estimated reserves.[33] The Etchegoin formation was opened up as a good gas producer by Richfield in 1945. The discovery well produced 5,000,000 cubic feet per day. The 68-29 pool, discovered by Richfield in 1947, produced an initial 441 barrels per day of oil from basal Stevens sand from depths of 9,648 to 9,880 feet. The deepest well, Richfield's Coles Levee A 21-33, was drilled to 14,003 feet into lower Miocene, and found several productive intervals between 9,810 and 11,940 feet.[34]

Coles Levee, South. South Coles Levee field, discovered the same year as North Coles Levee, also produces from the Stevens sand, at approximately the same depths, but has had a total production of only about one-quarter that of North Coles Levee. Reserves are correspondingly smaller.

Ten Section. Ten Section field is another of the Central Valley fields which was located in a region of little topographic expression and no outcrops, by reflection seismograph. Shell Oil Company drilled the discovery well, KCL A-1 in 1936 to a depth of 7,888 feet into Stevens sand. The well produced 827 barrels per day of 60-degree gravity oil with a high gas-oil ratio. Later wells have produced oil in the gravity range of about 28 to 38 degrees. The structure is an anticline with an arcuate axis with a general east-west trend. Production reached a maximum in 1943 of 6,557,725 barrels and declined to 2,829,239 barrels in 1947. In 1947 Shell Oil Company drilled its deep test well, KCL A-53-30, in sec. 30, T. 30 S., R. 26 N., M.D., to a depth of 14,000 feet, testing several zones in progress. Production was finally developed in lower Stevens sand between 8,820 and

---

[33] Annual Review, Petroleum World, pp. 68-69, 1948.

[34] Summary of Operations, California Oil Fields, July-Dec. 1947, California Div. Oil and Gas, in press.

Kern County crude oil production and proven acreage by fields.

Field	Year of first production*	1947 production of oil (bbls.)*	Cumulative production of oil to January 1, 1948 (bbls.)*	Proved acreage as of June 30, 1947**
Temblor McKittrick Cymric	1898	7,222,059	112,063,183	3,285
Midway Sunset Buena Vista Hills	1900	30,502,614	1,064,407,525	43,035
Kern River	1900	3,728,276	301,638,781	7,160
Kern Front	1913	3,250,304	72,254,089	4,100
Lost Hills	1910	1,921,949	61,022,516	2,890
Belridge, North and South	1912	4,487,852	97,306,242	7,735
Elk Hills	1919	2,333,803	197,056,790	15,390
Wheeler Ridge	1923	78,987	4,453,619	230
Mount Poso	1926	5,150,828	97,210,906	2,990
Round Mountain	1927	3,085,459	53,145,229	2,315
Fruitvale	1928	2,391,235	40,872,671	2,020
Arvin-Mountain View	1933	1,890,320	50,055,421	1,835
Edison	1934	4,123,587	23,097,196	2,690
Greeley	1936	4,287,532	32,325,049	1,970
Ten Section	1936	2,829,239	41,730,373	1,880
Rio Bravo	1937	4,575,966	42,914,515	1,870
Coles Levee, North	1938	6,111,599	37,425,730	3,130
Coles Levee, South	1938	1,113,807	10,043,515	3,200
Canal	1937	738,570	13,244,152	780
Canfield Ranch	1938	8,368	161,233	50
Wasco	1938	91,579	4,651,832	200
Paloma	1939	3,220,865	8,246,097	5,330
Strand	1939	651,317	5,490,103	380
Union Avenue	1941	111,101	481,810	*80
Antelope Hills	1942	495,421	3,296,954	245
McClung	1943	4,000	107,653	10
Tejon	1943	1,187,495	1,918,828	870
Bellevue	1944	113,278	601,626	60
Gosford	1944	9,518	92,640	*80
Ant Hill	1945	533,115	1,252,138	305
Blackwell's Corner	1945	63,348	198,257	190
Santiago	1945	2,421,593	4,428,047	-------------
Sheep Springs	1945	277,647	650,828	*300
Rosedale	1945	34,730	113,047	*180
Salt Creek	1946	2,309,349	2,730,573	*240
Race Track	1945	766,314	1,488,499	-------------
Belgian Anticline	1947	150,350	150,350	*800
Poso Creek	1947	1,324,775	11,797,130	1,875
Bacon Hills	1947	30,559	30,559	10
Comanche Point	1947	1,065	1,065	*120
Jasmine	1946	56,455	58,505	40
Kern Bluff	1946	16,844	18,274	*240
McDonald Anticline	1945	22,093	43,389	35
Devils Den	-------------	9,930	33,497	*175

* Data from Annual Review, Petroleum World, 1948.

** Data from Summary of Operations, California Oil Fields, Jan.-June 1947, State Division of Oil and Gas.

8,860. The well was producing 220 barrels per day at the end of the year. In early 1948 a second Shell Oil deep test well, KCL 73-30, cored the top of the 53 sand at 8,870 feet but found it barren and plugged back to 8,185 feet, developing small production in the upper Stevens sand.

Ten Section is an outstanding example of a field undergoing scientific unit development, made possible by its simple structure and control by one operator.

Canfield Ranch. Canfield Ranch production has declined more or less steadily since discovery in 1938 to about 8,000 barrels a year, making it one of the smallest fields in Kern County. Production comes from a depth of about 8,000 feet in the Stevens zone.

Paloma Oil and Gas Field. Paloma (Buena Vista Lake) was discovered as a gas field in 1934 by Ohio Oil Company and had produced over five billion cubic feet of dry gas to the end of 1947, making it an important gas field, but not among the largest in the state. In 1939 a very high gravity oil pool was discovered in Stevens sand at a depth of more than 10,000 feet. This was established as a condensate pool. In 1942 the limits of the field were extended about 1 mile north with the discovery of the "Black oil" pool in Stevens sand yielding oil of 34- to 50-degree gravity. In 1947 development along the northeast boundary of the field extended the proven limits by 780 acres. Paloma was among the 12 most actively drilled fields in California in that year; that activity continues in 1948.

In August 1948 a suit was filed in Kern County by Western Gulf Oil Company and Texas Oil Company alleging that various other companies have been removing gas from some parts of the field while the plaintiffs have been returning gas to formation under a unit-development plan to maintain gas pressures and to gain the highest ultimate recovery. The court decision will be important in its influence on other such unit-development programs.

Southern Fields

Wheeler Ridge. The Wheeler Ridge field, at an elevation of about 2,000 feet in the Tehachapi foothills along the south border of the San Joaquin Valley, was discovered by Standard Oil Company well KCL 2-1 in 1923. The well produced 323 barrels per day of 26-degree gravity oil from 2,185 feet. The structure is an east-trending asymmetrical, closed anticline; producing horizons are in the lower Santa Margarita-upper Maricopa and in the lower Maricopa formations. Deeper tests have failed to prove production in Vaqueros, Oligocene, and Eocene formations.

A new accumulation was found in the Coal Canyon area, about half a mile west of the Wheeler Ridge field in May 1948 by Richfield Oil Company well KCL 72-29. By July 1 there were three producing wells in sec. 29, T. 11 N., R. 20 W., S.B., averaging about 75 barrels per day. Production is from depths of 1,000 feet or less.

Tejon. The Tejon oil field had produced nearly two million barrels of oil by the end of 1947, but production was declining and drilling had ceased by early 1948. The field was discovered in 1937 by Universal Consolidated Oil Company whose Grapevine 1 produced an initial 160 barrels per day of 21- to 23-degree gravity oil below a depth of 3,800 feet from an upper Miocene sand. Later, in 1943, a Chanac pool was developed.

Comanche Point Area. Tejon Hills Oil Company discovered a new shallow field in July 1948 in sec. 10, T. 11 N., R. 18 W., S.B., at a depth of 418 feet in the Santa Margarita formation. The discovery well showed an initial flow of 50 barrels per day of 33-degree gravity oil. A subsequent well cored 25 feet of oil sand between 115 and 140 feet. By September 1, four wells producing between 20 and 70 barrels per day were completed.

Tejon Hills Area. Shallow production was found in 1947 in sec. 32, T. 12 N., R. 18 W., S.B., by Horace Steele and L. C. Gould in their Gould 1 well. Production was 30 barrels per day of 12-degree gravity oil from basal Chanac and Santa Margarita. The top of the oil sand was at a depth of about 400 feet. Structure is probably a faulted anticlinal nose.

Dry Gas Fields

The largest production of gas from Kern County fields has come from fields which are also great oil producers, such as Buena Vista Hills (in Sunset field) and Elk Hills. However, four fields have produced no oil and may be classed as strictly dry-gas fields. These are Trico, Semitropic, Buttonwillow, and Bowerbank.

These fields produce nearly pure methane from low closed anticlines from various thin sand zones of the San Joaquin clay formation. Although gentle topographic highs mark the positions of the structural highs, seismographic work has been responsible for the actual discoveries of the three fields post-dating Buttonwillow.

Trico. Trico gas field is the largest and most important of the four dry-gas fields in Kern County. It was the largest producer in 1947 and the most active from the standpoint of new wells drilled. According to the Division of Oil and Gas, 42.5 percent of all successful dry-gas wells drilled in California in 1947 were in this field.

The field was discovered in 1934 by the Trico Oil and Gas Company, which drilled a blow-out discovery well to a depth of 2,476 feet into the San Joaquin clay formation. The structure is a northwest-trending closed anticline approximately 9 miles long by 4 miles wide. It crosses county boundaries, extending southward from Tulare into Kern County. In 1945 a new well discovered the deeper Atwell Island zone in the lower San Joaquin formation and also extended the field to the northwest in Tulare County.

Trico production for 1947 was more than two and one-half times that for 1946, and reserves were set at the largest figure in the history of the field.

Semitropic. Peak production of dry gas from the Semitropic field came in 1942; there has been a general decline during the last 3 years. Total production for the year 1947 was about one-tenth that of Trico. The field is of declining importance.

Standard Oil Company Hill 1, the discovery well, produced an initial 107,000 thousand cubic feet of gas per day from the San Joaquin formation after first blowing out and burning in 1935. The field produces from several sand horizons of the San Joaquin clay. The structure is a long narrow closed anticline trending northwestward.

Buttonwillow. The discovery of this oldest central valley floor field was by Milham Exploration Company in 1926 as a result of observation of a gentle topographic high. The structure is now known to be a northwest trending closed anticline about three times as long as it is wide. The discovery well blew out and destroyed its rig and it was in 1927 that the first successful well was completed, giving an initial gas production of 11,700 thousand cubic feet per day from a sand bed of the San Joaquin clay. At least four sand horizons produce gas. Early in 1942 the Texas Company began production of gas from the south Buttonwillow dome.

Annual production figures for Buttonwillow are irregular, showing peaks for 1930 and 1935 and then a general decline during the last 2 years as the field nears the end of its productive life.

Bowerbank. Bowerbank is the latest dry-gas discovery in Kern County, but is apparently a small field and has declined in annual production since 1944. The discovery well, drilled in 1942, was Texas Company S. P. 47-15, which yielded an initial 10,000 thousand cubic feet per day from a depth of 4,262 feet. Production comes from a San Joaquin clay horizon in an anticlinal structure. No development has taken place since 1943.

*Summary of Dry Gas Production **
in Kern County

Field	*1947 production (MMcf)*	*Cumulative production to 1-1-48*	*Proved acreage of gas fields*
Bowerbank	405	3,263	1,360
Buena Vista Hills	878	119,928	–
Buttonwillow	1,582	33,799	560
Coles Levee	2,555	20,584	–
Elk Hills	3,318	83,174	–
McKittrick	–	1,033	–
North Midway	–	1,826	–
Paloma	139	5,115	–
Semitropic	988	12,082	1,600
Trico **	9,623	38,379	9,988**

* Data from Annual Review, Petroleum World, pp. 246-247, 1948.
** Includes Tulare and Kings Counties.

STATE GEOLOGICAL SUVEYS*

By Wilson M. Laird **

OUTLINE OF REPORT

	Page
Stimulated development of natural resources	300
Scope and activities of state surveys	300
Federal and state cooperation	300
Training of men in survey work	301
The financial aspect	302
Alabama	302
Arizona	302
Arkansas	302
California	303
Colorado	303
Connecticut	303
Florida	303
Georgia	304
Idaho	304
Illinois	305
Indiana	306
Iowa	306
Kansas	306
Kentucky	308
Louisiana	308
Maine	308
Maryland	308
Michigan	309
Minnesota	309
Mississippi	309
Missouri	309
Montana	310
Nebraska	310
Nevada	311
New Hampshire	311
New Jersey	311
New Mexico	311
New York	312
North Carolina	312
North Dakota	312
Ohio	313
Oklahoma	313
Oregon	313
Pennsylvania	314
Rhode Island	314
South Carolina	315
South Dakota	315
Tennessee	31
Texas	315
Vermont	315
Virginia	316
Washington	316
West Virginia	317
Wisconsin	317
Wyoming	317

---

* Reprinted from *The American Year Book, 1948,* by permission of Thomas Nelson & Sons, publishers.

** State Geologist of North Dakota.

STIMULATED DEVELOPMENT OF NATURAL RESOURCES

In the present time, sometimes known in the vernacular as "The Atomic Age," we find that the natural resources of this and every other country are of extreme importance. Of course, the immediate interest as far as the atomic age is concerned are those minerals which are possibly radio-active. However, all natural resources are important in this, as well as any other age. The United States has been singularly blessed with abundance of natural resources, but the recent war and high post-war demands have not only depleted some of our resources to a marked degree, but are constantly causing inroads on the ones in which we are as yet still relatively self-sufficient. Therefore, the state geological surveys, or their equivalents the state bureaus of mines, have increased where possible their investigations and have helped to stimulate the development of natural resources in their respective territories.

As the United States is a large and varied area containing many different geological conditions, no two states have exactly the same natural resources in the same quantities. On one hand some states have abundant resources of coal; others have abundant resources of the metals; still others have abundant resources of oil; many have non-metallic products such as building stone, clays, sodium sulphate and other minerals which are also extremely important. The importance of building materials, such as gravel and sand, should not be overlooked. In fact, the gravel and sand industry surpasses in monetary value some other less prosaic minerals as far as the country as a whole is concerned. The importance of construction materials is extremely marked in areas where abundant deposits of sand and gravel are not readily available and where large construction projects, such as the dams on the Missouri River, are about to take place.

SCOPE AND ACTIVITIES OF STATE SURVEYS

The state geological surveys have been for many, many years interested in developing the natural resources in their own area and to this end they have conducted natural resource surveys, have done geologic mapping, and a number of them have done actual development or pilot plant work on the utilization of these natural resources for the benefit of all concerned. These states which have gone so far in the support of their state geological surveys are to be highly complimented. Probably the most outstanding example of industrial research for the benefit of the state and industries therein is that being done at the present time in the Illinois Geological Survey.

A number of state surveys have had a long and illustrious history. In 1948, the 100th anniversary of the Alabama Geological Survey will be celebrated. Several of the surveys, notably Pennsylvania, New York, as well as several others, are well over 100 years old already and during their life span they have done a tremendous amount of excellent work that has been done by no other agency, either private or public.

FEDERAL AND STATE COOPERATION

As time passes we are learning that there is more and more to be gained by cooperation between the state geological surveys and the federal government agencies, particularly the U. S. Geological Survey. This cooperation varies from financial arrangements, whereby the states furnish half the money and the federal government furnishes the other half and all of the personnel for the cooperative project, to projects where the state supplies men and the federal government supplies men to work together on a project. In all instances these cooperative projects have been of benefit, both to the state and to the federal government, and as far as the states are concerned there is a feeling that in most cases they are very well satisfied with the results. The realm of cooperation takes in not only actual geologic studies, but also ground-water work, surface water work and topographic mapping.

At the present time there is a great interest in ground-water work due to the urgency that a number of areas, particularly towns, have felt for the development of adequate water supplies. In the more arid parts of the country the matter of underground water is one of considerable importance, in view of the fact that there is not sufficient surface supply to accommodate the needs for the surrounding territory. Topographic mapping is also of extreme importance, owing to the fact that little can be done in a geologic way without adequate base maps. These maps also are used, not only by state highway departments, but also by recreation officials and planning authorities.

In the great central portion of the country in the Missouri River basin there is at the present time a tremendous development going on under the supervision of both the Army Engineers and the Bureau of Reclamation. These agencies have been calling upon, not only other agencies of the federal government, but also the state geological surveys for information on the natural resources and related problems in their respective areas. In this respect the state surveys have been glad to cooperate because it is felt that this development will be of great benefit, not only to the individual states, but to the entire country. In the Missouri basin area there are planned a large number of dams for flood control and navigation, as well as irrigation. Should all of the proposed areas be irrigated and should all of these dams be constructed, it would be a tremendous boon to the region. In the area affected by these dams, undoubtedly a large number of people who will settle on farms will come into the region. Furthermore, a considerable amount of industry will probably follow because of advantageous location near natural resources, as well as abundant electric power which will be developed from the dams.

TRAINING OF MEN IN SURVEY WORK

Another part that the state geological surveys play, and one which is not particularly advertised, is in the training of men not only for the federal government but also for private industry and teaching positions. The state geological surveys have had on their staffs at one time or another a large number of people who have gone out into the various branches of the geological sciences. This training has been all to the good for the individuals, but it has not been entirely one-sided because the state geological surveys have been able to benefit by having young, vigorous men who were on their way up on their staffs and who have contributed a great deal to the good work that has been done by the state geological surveys. A number of the surveys are employing graduate students during the summer months for field work which may be used as the basis for a Master's or Doctor's thesis in some university. In this way the state geological survey benefits by getting an area needing geologic work mapped relatively cheaply, and at the same time the student receives the benefit from his work for his thesis problem.

THE FINANCIAL ASPECT

The state geological surveys are, of course, totally dependent upon appropriations from their respective state legislatures. It is to be hoped, in view of the large demand for the survey type of geologic work, that the appropriations will be continued on a larger basis in the coming years. This is dependent to a large degree on business conditions and the general tax structure as a whole. In any event, the state geological surveys need additional funds for hiring adequately trained men, for equipping well designed and well cared for buildings, and for research purposes. In the minds of most competent observers there has been more received in a monetary way from the work of the geological surveys in the respective states than the surveys have ever had appropriated to them. Therefore, it would seem that it would be a very fine business investment if the amount of money spent on state geological surveys was increased.

ALABAMA

Organization.—Geological Survey of Alabama, University, Alabama, Dr. Walter B. Jones, State Geologist.

Basic and Economic Geology.—Projects: Well logs, Coosa coal field; Brown iron ores of Alabama.

Water Resources.—Projects: Natural water losses of Alabama; Ground-water of south Alabama. *Publications:* Ground-Water Investigations in the Mobile Area, Alabama (Bull. 38).

Others.—Publications: The Theridiidae or Comb-Footed Spiders of Alabama (Mus. Paper 22).

ARIZONA

Organization.—Arizona Bureau of Mines, Tucson, Arizona, Dr. T. G. Chapman, Director.

Basic and Economic Geology.—Projects: Relation of structure to mineralization in central Arizona; Arizona minerals; Cooperation with State Land Department; Zinc and lead deposits of Arizona; Barite; Perlite; Engine sand; Light-weight aggregates. *Publications:* Minerals of Arizona (Bull. 153).

Others.—Projects: Spectrographic studies of contact deposits; History and statistics of Arizona mining. *Publications:* History of Mining in Pima County, Arizona; Progress and Trends in Mineral Dressing.

ARKANSAS

Organization.—Division of Geology, Arkansas Resources and Development Commission, Little Rock, Arkansas, Harold B. Foxhall, Director.

Basic and Economic Geology.—Projects: Study of significant wildcat wells in eastern Arkansas; Cooperative project with the Coal Division, U. S. Bureau of Mines in sampling Arkansas lignite deposits; Lignite to be tested for Montan wax content; Mapping and sampling of a molybdenite deposit in the Magnet Cove area; Mapping and study of the rutile deposits in the Magnet Cove area; Supervision and exploration project on a north Arkansas phosphate deposit; Sampling and ceramic testing of the Wilcox clays of the Gulf Coastal Plain in Arkansas. *Publications:* Brookite Deposit in Hot Spring County, Arkansas (Bull. 11).

Water Resources.—Projects: Stream gaging at 46 stations.

Topographic and Planimetric Mapping.—Projects: Cooperative topographic mapping with the U.S.G.S. of the Malvern Quadrangle.

Others.—Projects: Compilation of annual mineral production statistics for the state.

CALIFORNIA

Organization.—Division of Mines, Department of Natural Resources, San Francisco 11, California, Dr. Olaf P. Jenkins, Chief.

Basic and Economic Geology.—Projects: Tesla, Blue Lake, Lake Elsinore, Hollister, Copperopolis, St. Helena, Nipomo and Quien Sabe quadrangles; Mines and mineral resources of Napa County; California mineral production and directory of producers; Statistical bulletin; Guide book to Sierra Nevada; Tungsten Hills district; San Diego pegmatites; West Point tunnel. *Publications: California Journal of Mines and Geology,* Vol. 43, for January, April, July and October, 1947; Consolidated Index of Publications, Division of Mines and State Mining Bureau (Bull. 131); Minerals of California (Bull. 136); California Mineral Production and Directory of Mineral Producers for 1945 (Bull. 137); Iron Resources of California (Bull. 129); Geological Investigations of Chromite in California (Bull. 134); Placer Mining for Gold in California (Bull. 135); Copper Resources of California (in press).

COLORADO

Organization.—Colorado Geological Survey, Denver, Colorado, Dr. Ben H. Parker, State Geologist.

Basic and Economic Geology.—Projects: Cooperative work with the U.S.G.S. on the geology and mineral resources of Cripple Creek, San Juan, Kokomo, Ophir, Leadville-Minturn-Redcliff areas.

CONNECTICUT

Organization.—Connecticut Geological and Natural History Survey, Hartford 6, Connecticut, Dr. Edward L. Troxell, Director.

Basic and Economic Geology.—Projects: Two geologic studies in eastern Connecticut; Geologic study near Preston, Connecticut; Geologic study near Hammond Beach area; Study of Mollusks. *Publications:* Asilidae—the Robber Flies (Bull. 69); Spiders of Connecticut (Bull. 70).

Others.—Publications: Biennial Report.

FLORIDA

Organization.—Florida Geological Survey, Tallahassee, Florida, Herman Gunter, Director.

Basic and Economic Geology.—Projects: Micropaleontology; Geology and structure of Levy and Citrus Counties; Geology and structure of Jackson County; Correlation of well data; Prospecting for rare earths in cooperation with U. S. Bureau of Mines; General review of mineral resources in Florida; Preparation of mineral producers directory; Periodic investigation of fine character of basic clays and dolomites; Investigations of light weight aggregate and materials for making rock wool.

Water Resources.—Projects: Continuous cooperation with U.S.G.S. in ground water studies; Surface water studies, especially springs and lakes; Quality of water studies. *Publications:* Water Levels and Artesian Pressure in Wells in Southeastern States, Springs of Florida (Bull. 31).

Others.—Projects: Continued cooperation with University of Florida Engineering and Industrial Experiment Station, in prospecting clays. *Publications:* Elevations in Florida (Bull. 32); Seventh Biennial Report, Florida Geological Survey; Springs of Florida (map).

GEORGIA

Organization.—Department of Mines, Mining and Geology, 425 State Capitol, Atlanta, Georgia, Garland Peyton, Director.

Basic and Economic Geology.—Projects: Geology and mineral resources of Rabun, Towns and Habersham Counties; Investigation of mica in mica schists to determine its suitability for use in grinding mica; Investigation of vermiculite deposits in Georgia; Investigation and exploration of amphibole asbestos deposits; Investigation of sericite phyllites in Georgia; Investigation of pegmatitic type deposits as a source of grinding mica; Investigation of kaolin and other mineral resources of central east Georgia. *Publications:* Directory of Mineral Producers; List of Publications on Geology and Mineral Resources of Georgia (Circular 1); Geology and Mineral Resources of the Paleozoic Area of Northwest Georgia in cooperation with T.V.A. (in press); Geologic map of northwest Georgia in cooperation with T.V.A., scale four miles to one inch.

Water Resources.—Projects: Hydrologic studies of limestone terranes in Baker and Mitchell Counties in cooperation with the U.S.G.S. and Emory University; A study of salt water encroachment in the Savannah area, in cooperation with U.S.G.S.; Geology and ground water resources of the Paleozoic area, in cooperation with U.S.G.S.; Geology and ground water resources of eight counties in the Atlanta area, in cooperation with U.S.G.S.

Topographic and Planimetric Mapping.—Projects: Map of the mines, quarries and prospects in the Paleozoic area of northwest Georgia in cooperation with T.V.A.

IDAHO

Organization.—Idaho Bureau of Mines and Geology, Moscow, Idaho, A. W. Fahrenwald, Director.

Basic and Economic Geology.—Projects: Black Sand (monazite) resources surveys; Geological survey and mapping of the Yankee Fork area, Custer County; Geological mapping of the Little Lost River Mountain area, Butte County; Resources study of Diatomite; Beneficiation and processing of Idaho phosphate rock. *Publications:* A Geological Reconnaissance of the Hailey Gold Belt, Blaine County, Idaho (Pamph. 76); Beneficiation Tests on Gypsum Rock from Washington County, Idaho (Pamph. 77); Metallurgical Tests on the Manganese Bearing Sands of Payette County, Idaho (Pamph. 78); Beneficiation of Idaho Phosphate Rock (Mineral Resources Report No. 3); Diatomite Deposits of Southwestern Idaho (Mineral Resources Report No. 4).

ILLINOIS

Organization.—State Geological Survey Division, State Department of Registration and Education, Urbana, Illinois, Dr. M. M. Leighton, Chief.

Basic and Economic Geology.—Projects: Areal investigations and geologic mapping; Engineering geology reports on highway conditions, damsites, etc.; Pennsylvanian stratigraphy; Mississippian stratigraphy; Silurian stratigraphy; Cambro-Ordovician stratigraphy; Pleistocene system; Micropaleontological studies; Paleobotany of the Pennsylvanian; Geology and oil and gas resources of the Illinois basin; Secondary recovery of oil in Illinois; Studies of reservoir conditions in Illinois oil pools; Scouting of drilling wells and cooperation with Illinois Scout Check; Mapping and study of Illinois coal resources; Lithological and botanical constitution of Illinois coals; Studies to determine the usefulness of coal spores as index fossils; Briquetting of Illinois coal without binder; Investigation of combustion behavior of Illinois coal to develop improved stoker fuels; Investigation of suitability of low-sulfur Illinois coals for use in production of metallurgical coke; Chemical study of tars prepared from Illinois coals in commercial and pilot plant coking operations; The chemical constitution of Illinois coals; Proximate and ultimate analyses of Illinois coals; Geologic study of mine roof conditions; Fluorspar resources of southern Illinois; Utilization of fluorspar; Clay resources of Illinois; Petrology of of Illinois clays; Special uses for Illinois clays and shales; Application of clay mineralogy to problems of the origin, discovery and production of oil; Clay mineralogy as related to soil materials and engineering problems; Limestone resources of Illinois; Sand and gravel resources of Illinois; Investigation of the physical properties of Illinois silicas; Viscosity of silicate melts. *Publications:* Pennsylvanian Ostracodes in Illinois (Bull. 70); Preglacial Erosion Surfaces in Illinois (R.I. 118); Upper Kincaid (Mississippian) Microfauna from Johnson County, Illinois (R.I. 122); King Oil Field, Jefferson County, Illinois (R.I. 119); Developments in Eastern Interior Basin in 1945 (I.P. 53); Oil and Gas Development in Illinois in 1945 (I.P. 54); Flood Tide in Illinois (Cir. 125); Correlation of Domestic Stoker Combustion with Laboratory Tests and Types of Fuels, II. Combustion Tests and Preparation Studies of Representative Illinois Coals (R.I. 120); Coke—A Key Industrial Material (Cir. 127); Trends in Coal Utilization (Cir. 128); Southern Illinois Novaculite and Novaculite Gravel for Making Silica Refractories (R.I. 117); Agstone Used in Illinois in 1945 (Cir. 123).

Water Resources.—Projects: Ground-water geology of industrial, urban and special areas; Electrical earth resistivity surveys for subsurface water-bearing sand and gravel deposits; Geophysical logging of water wells; Cooperation with Illinois Water Well Drillers Association.

Topographic and Planimetric Mapping.—Projects: Alton, Augusta, Buckley, Camp Grant, Camp Point, Chatham, Columbia, Crete, Cullom, Davenport, Dunlap, Fairfield, Hillsboro, Joliet, Kansas, Kimmswick, Leroy, Mendon, Milan, Morrisonville, Muscatine, Olney, Pana, Paris, Peoria, Peotone, Prairie Home, Rockford, St. Charles, Spring Bay, Stewardson, Strawn, Wapello, Waterloo and Woosung quadrangles. *Publications:* Gilman and Ramsey Quadrangles.

Others.—Projects: Economic review of mineral industries; Long-term manufacturing opportunities in Illinois; Handbook of fuels data—with special reference to fuel consumption in the Illinois coal market area; Studies of Southern Illinois economic problems; Investigation of the transmission of radio waves through rock strata. *Publications:* Geologic Map of Illinois; Soil Survey maps; Illinois Mineral Industry in 1945 (R.I. 121); *What About Our Minerals?* A Quiz Book on the Geology and Mineral Resources of Illinois (Cir. 124); Operation of the Illinois State Geological Survey (Cir. 126).

INDIANA

Organization.—Division of Geology, Indiana Department of Conservation, Bloomington, Indiana, Dr. Charles Deiss, State Geologist.

Basic and Economic Geology.—Projects: Completed flights totaling 20,000 square miles for airborne magnetometer survey of Indiana; Completed directory of mineral producers in Indiana; Microscopic studies of the Silurian and Devonian formations along the Cincinnati arch; Geologic and mineral resources of Jasonville quadrangle; Resurvey of coal lands of Indiana; Completed examination and sampling of 85 commercial limestone and shale deposits in Indiana. *Publications:* Silurian and Devonian Rocks of Southeastern Indiana; Wyandotte Cave.

Water Resources.—Projects: Cooperative program with the U.S. G.S.

Topographic and Planimetric Mapping.—Projects: Cooperation with the U.S.G.S.

Others.—Publications: Oil and Gas Developments in Illinois and Indiana in 1946; Data on Indiana in F. H. Lahee Report on Exploratory Drilling in 1946.

IOWA

Organization.—Iowa Geological Survey, Iowa City, Iowa, Dr. H. Garland Hershey, Director and State Geologist.

Basic and Economic Geology.—Projects: Pleistocene history of Mississippi River; Stratigraphy of Upper Des Moines Series; Geology of Floyd County; Geology of Shelby County; Subsurface geology of Cambrian strata of Iowa; Revision of Kinderhook strata of Iowa; Bibliography of geology of Iowa; Subsurface geology of the Osage and Kinderhook Series in southeastern Iowa; Subsurface geology of Ordovician strata in Iowa; The Neda zone in Iowa; Summary of agricultural limestone resources in south-central Iowa; Mineral production reports.

Water Resources.—Projects: Ground-water resources of Cerro Gordo County; Geology and ground-water resources of Webster County; Geology and ground-water resources of Cedar Rapids and vicinity; Mineral analysis of underground waters of Iowa; Surface water resources of Iowa.

Others.—Publications: Mineral Resources Map of Iowa.

KANSAS

Organization.—State Geological Survey of Kansas, Lawrence, Kansas, Dr. Raymond C. Moore, Director of Research and State Geologist, Dr. John C. Frye, Executive Director.

Basic and Economic Geology.—Projects: Geology and oil and gas resources of Crawford County; Collection of mineral statistics in cooperation with U. S. Bureau of Mines; New mineral resources map of Kansas; Geologic cross sections in eastern Kansas; General stratigraphic and lithologic studies in eastern Kansas; Chemical analyses of Kansas rocks and minerals; Oil and gas resources of Bourbon County, Neosho County, Miami County and Chautauqua County; Oil and gas developments in western Kansas during 1947; Oil and gas developments in eastern Kansas; Structural development of the Salina Basin; Subsurface rocks of Upper Cambrian and Lower Ordovician age in Kansas; Investigation of oil shales in Kansas; Collection of well samples, cores, and logs; Subsurface stratigraphy along the west flank of the Central Kansas Uplift; Lignite resources of the Dakota formation of Cretaceous age in North Central Kansas; Chemical study of coals from the southeast Kansas coal fields; Geophysical investigations in the Kansas part of the Tri-State zinc and lead field; Experimental development of lightweight aggregates from clay, shale, loess, and volcanic ash; Field and laboratory study of anhydrite-gypsum relationships; Molding sand resources of Kansas; A study of flint gravel deposits in eastern Kansas; Industrial uses of "ceramic slag"; Petrographic and chemical study bearing on the usefulness of Kansas chalk deposits; Special tests and study of clays near Great Bend, Norton, and other communities for proposed brick and tile plants. *Publications:* Coal Resources of the Wabaunsee Group in Eastern Kansas (Bull. 63); Cretaceous Stratigraphy of the Belvidere Area, Kiowa County, Kansas (Bull. 64, part 6); Clays of the Dakota Formation in Kansas (Bull. 67); Exploration for Oil and Gas in Western Kansas During 1946 (Bull. 68); Coal Reserves in Kansas (Bull. 70, part 1); Magnetic Survey of the Bala Intrusive, Riley County, Kansas (Bull. 70, part 2); The Late Pleistocene Loesses of Central Kansas (Bull. 70, part 3); Cemented Sandstones in the Dakota and Kiowa Formations, Kansas (Bull. 70, part 4); Magnetic Survey of Southeastern Crawford County, Kansas (Bull. 70, part 5); Oil and Gas Investigations, Preliminary Cross Section No. 3, Subsurface Geologic Cross Section from Ford County, Kansas to Dallam County, Texas; Oil and Gas Investigations, Preliminary Cross Section No. 4; Subsurface Geologic Cross Section from Scott County, Kansas to Otero County, Colorado; Oil and Gas Investigations, Preliminary Cross Section No. 5; Subsurface Geologic Cross Section from Trego County, Kansas to Cheyenne County, Colorado.

Water Resources.—Projects: Geology and ground-water resources of the "Equus beds" area; Geology and ground-water resources of Pawnee and Edwards counties; Geology and ground-water resources of Jewell county; Ground-water resources of the Kansas City industrial area; Ground-water resources of the lower Arkansas valley; Ground-water resources in the Smoky Hill Valley from Lindsborg to Junction City; Deep-water supplies of southeastern Kansas; Geology and ground-water resources of the following counties: Stafford, Barton, Norton, Republic and northern Cloud, Rice, Pawnee Valley; Geology and ground-water resources along the north fork of Solomon River; Geology and ground-water resources of Wichita and Greeley counties; Observation-well program involving water level measurements in approximately 450 wells. *Publications:* Geology and Ground-water Resources of Kiowa County, Kansas (Bull. 65); Geology and Ground-water Resources of Scott

County, Kansas (Bull. 66); Geology and Ground-water Resources of Seward County, Kansas (Bull. 69).

Topographic and Planimetric Mapping.—Publications: Oswego and Parsons Quadrangles.

KENTUCKY

Organization.—State Department of Mines and Minerals, Lexington, Kentucky, Daniel J. Jones, State Geologist.

Basic and Economic Geology.—Publications: Relation of Sand Deposits at Tip Top, Kentucky, to the Meramec-Chester Boundary; Map showing Knox Dolomite Tests.

LOUISIANA

Organization.—Louisiana Geological Survey, Baton Rouge, Louisiana, Leo W. Hough, State Geologist.

Basic and Economic Geology.—Projects: Geology of Red River, De Soto, Webster, Allen and Beauregard Parishes; Reserve estimates; Basic and recalculations on oil and gas; Investigation of ceramic possibilities of clay resources of the State. *Publications:* Geology of Red River and De Soto Parishes.

Water Resources.—Projects: Special investigations in specific problem areas. *Publications:* Ground Water Resources in the Monroe Area, Louisiana.

Others.—Publications: Oil and Gas Map of Louisiana, Revised 1947 edition.

MAINE

Organization.—Maine Geological Survey, Orono, Maine, Dr. Joseph M. Trefethen, State Geologist.

Basic and Economic Geology.—Projects: Geology of part of coastline; Limestone; Diatomaceous earth; Feldspar; Serpentine. *Publications:* Manganese deposits of Aroostook County, Maine (Bull. 4); Report of State Geologist, 1945-46.

MARYLAND

Organization.—Department of Geology, Mines and Water Resources, Baltimore 18, Maryland, Dr. Joseph T. Singewald, Jr., Director.

Basic and Economic Geology.—Projects: Geologic mapping of Montgomery, Charles and Washington counties; Subsurface geology of eastern shore; Logging cores of U. S. Bureau of Mines drilling Georges Creek Basin; Fire clays of western Maryland. *Publications:* Carroll and Frederick Counties Report.

Water Resources.—Projects: Ground-water resources of Baltimore industrial area; Ground-water resources of southern Maryland; Conversion of remaining non-recording to recording gaging stations.

Topographic and Planimetric Mapping.—Projects: Topographic mapping of Garrett County; Revision of topographic maps of Kent and Montgomery counties. *Publications:* Prince George's County.

MICHIGAN

Organization.—Geological Survey Division, Department of Conservation, Lansing, Michigan, Gerald E. Eddy, State Geologist.

Basic and Economic Geology.—Projects: Limestones of southeastern Michigan; Niagaran formation; The Pleistocene; Public education in geology through lectures and magazine activities; Silurian and Ordovician; Stratigraphic research in petroliferous formations; Study of geology of Iron County; Study of geology of Dickinson County; Study of geology of western Marquette Range. *Publications:* Occasional Papers for 1946 on the Geology of Michigan.

Water Resources.—Projects: Study of water wells of the state; Study of water supply problems—Houghton-Hancock, Bessemer, Wakefield, Escanaba; Ground water fluctuations in north-central Michigan; Lake level problems. *Publications:* Ground-Water Resources of Alma Area; Ground-Water Resources of Battle Creek; Well Logs and Bedrock Geology of Gratiot County, Genesee County, Calhoun County, Kalamazoo County, Oakland County.

Others.—Publications: Pleistocene Geological Map of the Southern Peninsula; Annual Survey and Valuation of Iron and Copper for the State Tax Commission.

MINNESOTA

Organization.—Minnesota Geological Survey, Minneapolis, Minnesota, Dr. George M. Swartz, Director.

Basic and Economic Geology.—Projects: Geology of Cook County; Glacial geology of Cook County; Geology of the Duluth area; Revision of stratigraphy of Cambrian and Ordovician; Revision of geology of the Cuyuna Range; Magnetics of north central Minnesota; Restudy of the clays and shales of Minnesota. *Publications:* The geology and Underground Waters of Northeastern Minnesota, Minnesota Geological Survey (Bull. 32).

MISSISSIPPI

Organization.—Mississippi State Geological Survey, University, Mississippi, Dr. William C. Morse, Director and State Geologist.

Basic and Economic Geology.—Projects: Three projects in general geology; Two projects in nonmetallic minerals. *Publications:* Itawamba County Mineral Resources (Bull. 64).

Water Resources.—Projects: Four projects. *Publications:* Geology and Artesian Water of the Alluvial Plain in Northwestern Mississippi (Bull. 65).

MISSOURI

Organization.—Department of Business and Administration Division, Geological Survey and Water Resources, Rolla, Missouri, Dr. Edward L. Clark, State Geologist.

Basic and Economic Geology.—Projects: Pennsylvania correlations; Pleistocene of Missouri; Geologic mapping of local areas; Berryman Quadrangle; Steelville Quadrangle; Hermitage Quadrangle; Igneous rocks of Missouri; Osage Basin studies; Geology of St. Louis County;

Reclassifying coals of Missouri as to age; Studies in southeastern Missouri lead belt and adjoining counties; Structure southwest Missouri zinc and lead district; Geophysical work Annapolis and Palmer areas; Miscellaneous mineral property examinations and studies; Inventory of Missouri clays; Limestone quarry investigation; Dolomite quarry investigation and agricultural lime; Limestone in St. Genevieve County; Limestone in St. Louis. *Publications:* Post-Devonian Igneous Activity in Southeast Missouri (R.I. No. 5); Limestone and Dolomites in St. Louis County (R.I. No. 5).

Water Resources.—Projects: Gaging of eighty-seven stations, pump tests and acidizing recommendations deep wells; Examination of well cuttings; Ground-water at Lake City, Missouri. *Publication:* Groundwater in Agriculture (I.C. No. 2).

Topographic and Planimetric Mapping.—Projects: Continuous mapping of twelve quadrangles. *Publications:* Mt. Aure, Corridon, Sinkin, Blythedale, Missouri City, Birchtree, Grandin, Green Ridge, Glascow, Lamoni and Chula.

Others.—Publications: Index Topographic Map; Dedication of Buehler Building (I.C. No. 1); Biennial Report of State Geologist, 1947.

MONTANA

Organization.—Montana State Bureau of Mines and Geology, Butte, Montana, Dr. Francis A. Thomson, Director.

Basic and Economic Geology.—Projects: Continuation of State geologic mapping; Study of deeper horizons as possible sources for petroleum; Geology and ore deposits of the Highland mining district; Study of the placer-gold deposits of Montana; Pegmatites of Madison County; Survey of nonmetallic mineral deposits of Montana; Preliminary survey of sodium sulphate deposits of Montana. *Publications:* Geology and Ore Deposits of Hecla Mining District, Montana; Dickite-Clay Deposits of Fergus County, Montana (Miscl. Cont. No. 9); Distribution of Sedimentary Rocks in Montana and the Northwestern Great Plains (Miscl. Cont. No. 8); Stratigraphic Sections of Upper Paleozoic and Mesozoic Rocks in South-Central Montana.

Water Resources.—Projects: Continuation of general ground-water studies.

Others.—Projects: Study of mining problems of small mine operators and prospectors; Mineral dressing studies for the beneficiation of Montana ores and nonmetallic minerals. *Publications:* Metallic Mineral Deposits of Montana (published in cooperation with the U.S.G.S.).

NEBRASKA

Organization.—Conservation and Survey Division, University of Nebraska, Lincoln, Nebraska, Dr. G. E. Condra, Director and State Geologist.

Basic and Economic Geology.—Projects: Surface and subsurface stratigraphic studies; Bryozoan studies; Pleistocene stratigraphic studies; Subsurface studies; Oil field studies; Coal deposits stratigraphic study; Mineral resource studies. *Publications:* The Iowan Till in Northeast Nebraska; Two reports on Bryozoa.

Water Resources.—Projects: Central and South-central Nebraska counties. *Publications:* Preliminary County Ground-Water Reports (6).

Others.—Projects: Soil inspection and correlation work; Conservation and industrial surveys; Soil resurvey Saunders County. *Publications:* Otoe and Lancaster County Soil Maps; Pre-Pleistocene Map of South-central Nebraska.

NEVADA

Organization.—Nevada State Bureau of Mines, Reno, Nevada, Jay A. Carpenter, Director.

Basic and Economic Geology.—Projects: Areal photography and mapping of the area between Ely and Eureka close to the neighborhood of the old famous mining district of Hamilton.

NEW HAMPSHIRE

Organization.—Mineral Resources Committee, New Hampshire State Planning and Development Commission, Durham, New Hampshire, T. R. Meyers, Geologist.

Basic and Economic Geology.—Projects: Preparation of report on the surficial geology of New Hampshire; Investigation of alumina-bearing mineral deposits of New Hampshire. *Publications:* Mineralogy of New Hampshire Sands; Till Deposits of New Hampshire.

Water Resources.—Projects: Continuation of ground-water studies.

NEW JERSEY

Organization.—Bureau of Geology and Topography, Trenton, New Jersey, Meredith E. Johnson, State Geologist.

Basic and Economic Geology.—Projects: Recording of new data on the geology and mineral resources; Investigation of ore genesis and structural relations as exposed in operating mines; Cooperation with Bureau of Mineral Research, Rutgers University, in investigations of industrial sands.

Water Resources.—Projects: Study of the ground-water situation in Newark and Harrison; Collection of information on the ground-water resources of the state.

Topographic and Planimetric Mapping.—Projects: Sheets 22, 23 and 24 of Topographic Atlas; Geodetic control system. *Publications:* Topographic Atlas Sheets 21, 22 and 23.

NEW MEXICO

Organization.—New Mexico Bureau of Mines and Mineral Resources, Socorro, New Mexico, E. Carter Anderson, Director.

Basic and Economic Geology.—Projects: Geology of the Sangre de Cristo Mountain region; Geology of the Sacramento Mountain region; Investigation of oil field corrosion problems; Secondary recovery problems in the oil fields; Engineering and production data in the oil fields; Mineral resources of Colfax and Taos counties; Examination of clay deposits. *Publications:* Geology of the Grand Quivira Quadrangle (Bull. 26); Contributions of New Mexico's Mineral Industry to World War II (Bull. 27); Pumice Aggregate in New Mexico—Its Uses and Potentialities (Bull. 28); Compilation of State Tax Law Relating to Mineral Properties in New Mexico (Circ. 13); Oil and Gas Production Data, Eddy County, New Mexico (Circ. 14); Tables of Fluorescent and Radioactive Minerals (Circ. 15); New Mexico Oil and Gas Production Data for 1946 (Exclusive of Lea County. Circ. 16).

Water Resources.—Projects: Ground water resources of Colfax County, San Miguel County and Eddy County.

Others.—Projects: Tables of fluorescent and radioactive minerals and their behavior under various lights; Compilation of state laws relating to mineral properties in New Mexico; Annual reports. *Publications:* Annual Report for the Fiscal Year, July 1, 1945 to June 30, 1946; Annual Report for the Fiscal Year, July 1, 1946 to June 30, 1947.

NEW YORK

Organization.—New York State Science Service, Office of the State Geologist, Albany, New York, Dr. John G. Broughton, Acting State Geologist.

Basic and Economic Geology.—Projects: Structural geology of Otsego County; Branch office established at Wellsville, New York; Collecting well data and carrying on geophysical and geological research; Magnetic survey of Adirondack region; Economic geology of Niagara dolomites. *Publications:* The Clinton of Western and Central New York (Bull. 341); Cayugoceras, an Upper Silurian Cephalopod; Holochoanites are Endoceroids; New Ordovician Nautiloids from New York; Iron Mining Comes of Age in New York State.

NORTH CAROLINA

Organization.—Mineral Resources Division, North Carolina Department of Conservation and Development, Raleigh, North Carolina, Dr. Jasper L. Stuckey, State Geologist.

Basic and Economic Geology.—Projects: Review of mineral industry 1936-1945; Oil possibilities; Coastal Plain of North Carolina; Exploration Deep River Coal Field; Light-weight aggregate resources of North Carolina; Pegmatite resources, Bryson City area, North Carolina; Talc deposits of North Carolina; Scrap mica resources of North Carolina; Barite deposits of North Carolina. *Publications:* The Geology and Mineral Resources of Guilford County (I.C. No. 6).

Water Resources.—Projects: Ground-water survey of North Carolina. *Publications:* Ground-water in the Neuse River Basin (I.C No. 5); A Possible New Source of Ground-water Supply in the Elizabeth City Area, North Carolina.

NORTH DAKOTA

Organization.—North Dakota Geological Survey, Grand Forks, North Dakota, Dr. Wilson M. Laird, State Geologist.

Basic and Economic Geology.—Projects: Geology of the Tokio Quadrangle; Eocene of North Dakota; Study of well samples; Lignite compilation; Sodium sulphate deposits; Cement rock and limestone investigation. *Publications:* Geology of the Flora Quadrangle (Bull. 22).

Water Resources.—Projects: Ground-water studies at Wimbledon, New Rockford, Zeeland, Cavalier, Sharon, Aneta, Hope, Portland, Minot, Mohall, Flaxton, Michigan, Kindred, Wyndmere and Litchville, North Dakota; Observation well studies; Cooperation with Missouri Basin ground-water studies. *Publications:* Ground-water Near Buxton; Ground-water of Fargo-Moorhead Area; Ground-water in Deposits of Ancient Lake Dakota, Dickey County, North Dakota.

OHIO

Organization.—Geological Survey of Ohio, Columbus 10, Ohio, John H. Melvin, State Geologist.

Basic and Economic Geology.—Projects: Monongahela formation; Coshocton County; Perry County; Lucas County; Holmes County; Athens County; Hocking County; Collecting well logs; Examination of cuttings; Washing and filing cuttings; Mapping; Mapping coal outcrops; Limestones of eastern Ohio; Sharon conglomerate; Mapping mineral industries. *Publications:* Geologic Interpretation of Scenic Features in Ohio (Reprint 3); Generalized Section of Rocks in Ohio (I.C. No. 4); Waynesburg Coal in Harrison and Northern Belmont Counties, Ohio, and Revision of Dunkard (Permian) Boundary (R.I. No. 1); Geologic Section of Chillicothe Test Core (R.I. No. 2); Ohio's Place in Mineral Industry in 1945; Limestones of Eastern Ohio; Sharon Conglomerate.

Others.—Publications: Reprinting of Geologic Map of Ohio; Mineral Industry Map of Ohio; Geologic Map of Holmes County; Maps showing outcrop and extent of Meigs Creek coal in Cumberland and Caldwell Quadrangles, accompanied by section.

OKLAHOMA

Organization.—Oklahoma Geological Survey, Norman, Oklahoma, Robert H. Dott, Director.

Basic and Economic Geology.—Projects: Revision of state geologic map; Geology and mineral resources, Tulsa County; Stratigraphy and areal geology of Arbuckle group; Cambro-Ordovician Arbuckle Mountains, south-central Oklahoma; Subsurface structure map of state; Manuscript on Haskell County; Manuscript on northern LeFlore County; Black sands (titaniferous magnetite) of Wichita Mountains; Royer dolomite—mapping central Arbuckle Mountains; Floating properties—volcanic-ash; Clays. *Publications:* Morrow series (Bull. 66).

Water Resources.—Projects: Beaver, Grady, Ottawa counties; Observation well program; Miscellaneous pumping tests and service calls.

OREGON

Organization.—Oregon State Department of Geology and Mineral Industries, Portland, Oregon, F. W. Libbey, Administrator.

Basic and Economic Geology.—Projects: Geologic map of Dallas and Valsetz quadrangles; Micro-fossil study of Tertiary formations; Study of nickel-bearing laterities in southwestern Oregon; Investigation of saline deposits in Lake County; Study of common brick clays. *Publications:* Mines and Prospects of the Mt. Reuben District, Josephine County (Bull. 34); Sodium Salts of Lake County, Oregon (GMI Short

Paper 17); Bibliography of Geology and Mineral Resources of Oregon (Bull. 33).

Water Resources.—Projects: Collection of water-well data in northeastern Oregon.

Others—Projects: Study of samples for radio-activity.

PENNSYLVANIA

Organization.—Bureau of Topographic and Geologic Survey, Harrisburg, Pennsylvania, Stanley H. Cathcart, Director.

Basic and Economic Geology.—Projects: Stratigraphy of the Cambrian, Ordovician, and Silurian systems exposed in central Pennsylvania; Geology of Bucks County; Aerial geology of the Philadelphia district; Guidebook to the geology in the vicinity of Philadelphia; Guidebook to geology along the Pennsylvania Turnpike, with supplements on tunnel geology and ground-water; Geology of southeastern Clearfield County; Subsurface stratigraphy of western Pennsylvania; The Butler Quadrangle; The Smethport Quadrangle; The Haskell Sand, McKean County; The McDonald Pool; Areal geology of New Florence Quadrangle; Iron-manganese ores of South Mountain; High-alumina clays of Cameron and Clinton counties. *Publications:* Manganese Minerals of Pennsylvania (Bull. M27); Oil and Gas Developments in the North Strabane Area (Bull. M28); Haskell Sand Core from the Coryville Pool, McKean County (P.R. 131); Geology and Mineral Resources of the Smicksburg Quadrangle (A-55).

Water Resources.—Projects: Detailed study of the Philadelphia District; Detailed study of the Pittsburgh District.

Topographic and Planimetric Mapping.—Projects: Norristown, Germantown, Colegrove, Emporium, Short Run, Galeton quadrangles. *Publications:* Glen Richey, Ramey, Wallaceton, Houtzdale, Cameron, Driftwood, First Fork, Sinnemahoning, Sky Top, East Stroudsburg, Bushkill, Twelve Mile Pond, Bitumen and Hyner Quadrangles.

Others.—Publications: Undrilled area map of Warren Quadrangle; Undrilled area map of southern Kinzua and northern Kane Quadrangles; Farm Line maps of the Butler Quadrangle.

RHODE ISLAND

Organization.—Rhode Island Industrial Commission, Mineral Resources Committee, Providence, Rhode Island, Dr. Alonzo Quinn, Chairman.

Basic and Economic Geology.—Projects: Bedrock geology of North Scituate Quadrangle; Surficial geology of North Scituate Quadrangle.

Water Resources.—Projects: Ground-water of Pawtucket Quadrangle; Ground-water of Georgiaville Quadrangle.

SOUTH CAROLINA

Organization.—State Geological Survey, Columbia, South Carolina, Dr. Lawrence L. Smith, State Geologist.

SOUTH DAKOTA

Organization.—South Dakota State Geological Survey, Vermillion, South Dakota, Dr. E. P. Rothrock, State Geologist.

Basic and Economic Geology.—Projects: Structure in Fall River County; Structure in Haakon County; Granite appraisal; Quartzite appraisal.

Water Resources.—Projects: Water level fluctuations in eastern South Dakota. *Publications:* Ground-water resources of the Sioux Falls area (R.I. 56); Ground-water fluctuations in eastern South Dakota (R.I. 59).

Others.—Publications: Nonmetallic Economic Products in South Dakota.

TENNESSEE

Organization.—Tennessee Division of Geology, Nashville, Tennessee, H. B. Burwell, State Geologist.

Basic and Economic Geology.—Projects: Geologic mapping of Great Smoky Mountain National Park area; Geologic mapping in west Tennessee; Stratigraphic and structural mapping of complex structure in east Tennessee; Subsurface stratigraphy and structure throughout Tennessee; Coal study with attendant detailed mapping; Mapping phosphate reserves. *Publications:* Barite, Fluorite, Galena, Sphalerite, Veins of Central Tennessee (Bull. 51); Geology of Nashville (Bull. 53); Geology and Mineral Deposits of Bumpass Cove, Unicoi and Washington Counties, Tennessee (Bull. 54); Pre-Chattanooga Stratigraphy in Central Tennessee (Bull. 55); Geology of the Carters Creek and Godwin Quadrangles; Subsurface Stratigraphy of Pickett and Northern Fentress Counties, Tennessee.

Water Resources.—Projects: Stream gaging in cooperation with U.S.G.S.; Ground-water study in cooperation with the U.S.G.S.

TEXAS

Organization.—Bureau of Economic Geology of the University of Texas, Austin, Texas, Dr. John T. Lonsdale, Director.

Basic and Economic Geology.—Projects: Geology of the Christmas Mountains; Catalog of Cretaceous Foraminifera; Geologic surveys in Trans-Pecos Texas; Pleistocene deposits of High Plains; Carboniferous rocks of the Llano region; Ellenburger group in central Texas; Iron ore in the Llano region, central Texas; Mineral resources of the Trinity River tributary area; High grade clay in the Cisco group, north Texas; High grade clay in east Texas; Glass and industrial sands in north Texas. *Publications:* Building Stones of Central Texas (Pub. 4246); The Ellenburger Group of Central Texas (Pub. 4621); Geological Resources of the Trinity River Tributary Area in Texas and Oklahoma; Iron Ore in the Llano Region, Central Texas (R.I. 2); The Carboniferous Rocks of the Llano Region of Central Texas (Pub. 4329); High-Grade Clay in Cisco Group, North Texas; The Geology of Texas, Vol. I, Stratigraphy (Bull. 3232).

VERMONT

Organization.—Vermont Geological Survey, Burlington, Vermont, Dr. Charles G. Doll, State Geologist.

Topographic and Planimetric Mapping.—Projects: Jay Peak, Irasburg, Enosburg Falls and Londonderry quadrangles.

Others.—Publications: Report of the State Geologist on the Geology and Mineral Industries of Vermont.

VIRGINIA

Organization.—Geological Survey Division of Virginia Conservation Commission, Charlottesville, Virginia, William M. McGill, State Geologist.

Basic and Economic Geology.—Projects: Outline of the geology and mineral resources of Smyth County; Geology and mineral resources of the Lynchburg Quadrangle; Geology and mineral resources of Clarke and Frederick counties; Geology and mineral resources of the Lovingston Quadrangle; Geology of the Blue Ridge in central Virginia; Geology and mineral resources of the Vesuvius Quadrangle; Geology and oil possibilities of the Ben Hur district, Lee County; Geology and oil resources of the Rose Hill district, Lee County; Geology of the Valzinco district, Spotsylvania County; Geology and mineral resources of the Gossan lead district and adjacent areas; Industrial limestones and dolomites in the James River basin west of the Blue Ridge; Mica deposits; Piedmont marble belt. *Publications:* Commercial Granites and Other Crystalline Rocks in Virginia (Bull. 64); Industrial Limestones and Dolomites in Virginia; Northern and Central Parts of Shenandoah Valley (Bull. 65); A Tectonic Intrusion of Shale in Rockbridge County, Virginia (Repr. Ser. 14); The Catoctin Formation in Central Virginia (Repr. Ser. 15).

Water Resources.—Projects: Ground-water resources in the Roanoke area; Geology and ground-water resources of the York-James peninsula; Geology and ground-water resources of the Coastal Plain in northeastern Virginia. *Publications:* Chemical Character of Groundwater in the Coastal Plain of Virginia (Bull. 68); Genesis of Groundwaters in the Coastal Plain of Virginia (Repr. Ser. 13).

Topographic and Planimetric Mapping.—Projects: The following quadrangles: Boone Mill, Broadway, Callaghan, Clifton Forge, Dillons Mill, Edinburg, Fort Seybert, Goodes, Goshen, Leesville, Moneta, New Canton, Peaks of Otter, Radford, Strasburg, Waiteville, Warm Springs and Williamsville.

Others.—Publications: Publications on the Geology and Mineral Resources of Virginia (Circ. 6); Geologic map and structure sections of the Rose Hill District; Detailed geologic map and structure sections of the Fenster Area of the Rose Hill District, Lee County, Virginia.

WASHINGTON

Organization.—Division of Mines and Geology, Olympia, Washington, Sheldon L. Glover, Supervisor.

Basic and Economic Geology.—Projects: Collecting and supplying highly varied information, chiefly of economic nature; Giving aid to exploration companies; Compiling history of exploration; Giving aid to coal operators; Investigation of antimony occurrences throughout the state; Preparation of spot maps with brief details and references covering all known metallic mineral occurrences in state; Preparation of directory of operators; Study of all saline deposits in state; Investigation of perlite and occurrences of obsidian; Preparation of spot maps with accompanying brief details and references covering all known nonmetallic resources; Preparation of directory of operators. *Publications:* 1947 Directory of Mining Operations (I.C. No. 13); Excerpts from "Washington Fuel Requirements and Supplies" (I.C. No. 14); Oil and Gas Exploration in Washington (I.C. No. 15); Coal and Coal Mining in Washington (R.I. No. 4R).

WEST VIRGINIA

Organization.—West Virginia Geological and Economic Survey, Morgantown, West Virginia, Dr. Paul H. Price, State Geologist.

Basic and Economic Geology.—Projects: Geologic Gazetteer; Stratigraphy of Greenbrier limestone; Roof strata of coal seams; Composition and properties of petroleum in West Virginia (Part II), Gas analyses; Dolomitic zone at base of Greenbrier limestone; Core analyses; Possibility of shaft mining Greenbrier limestone.

Water Resources.—Projects: Cooperative studies with U.S.G.S. *Publications:* Ground Water Conditions at Charleston, West Virginia (R.I. No. 2).

Others.—Projects: Spectrographic analysis of coal ash; Well sample studies. *Publications:* Analyses of West Virginia Brines (R.I. No. 1); Composition and Properties of Petroleum in West Virginia (R.I. No. 3, Part I); Future of Oil in West Virginia; Clays of West Virginia—Volume XVIII.

WISCONSIN

Organization.—Wisconsin Geological and Natural History Survey, Madison 6, Wisconsin, E. F. Bean, State Geologist.

Basic and Economic Geology.—Projects: Lead and zinc investigation in cooperation with the U.S.G.S.

Water Resources.—Projects: Ground water surveys in progress.

Topographic and Planimetric Mapping.—Projects: Areal mapping in cooperation with the U.S.G.S. *Publications:* Planimetric maps of Ashland, Iron Lake, Mokuah and Granview.

Others.—Projects: Soil surveys in progress in Longlade, Barron and Richland counties.

WYOMING

Organization.—Geological Survey of Wyoming, Laramie, Wyoming, Dr. Horace D. Thomas, State Geologist.

Basic and Economic Geology.—Projects: Pre-Cambrian geology of the Laramie Mountains; Stratigraphy and paleontology of the Tertiary North Park formation; Geology of the Labonte area, Laramie Mountains; Geology of the Broadway lead and zinc claims; Pumice occurrences in the Leucite Hills; Cordierite in the Laramie Range. *Publications:* Stratigraphic Sections of Mesozoic Rocks in Central Wyoming (Bull. 38).

Water Resources.—Projects: Geology and ground-water resources of the Ranchester area; Geology and ground-water resources of the Glendo area.

Others.—Publications: Map of Goshen County, Wyoming, showing possible commercial deposits of sand and gravel.

INDUSTRIAL USES OF LIMESTONE AND DOLOMITE*

BY OLIVER BOWLES** AND NAN C. JENSEN†

OUTLINE OF REPORT

Page
Introduction ---- 319
Prior report ---- 325
Composition ---- 325
Lime included with limestone ---- 325
Statistical history of principal industrial uses ---- 325
Industrial applications ---- 325
  Metallurgy (flux) ---- 327
  Alkali ---- 327
  Refractories ---- 328
  Paper ---- 328
  Calcium carbide ---- 329
  Glass ---- 330
  Water purification ---- 330
  Fertilizer filler ---- 331
  Sugar ---- 331
  Whiting ---- 332
  Magnesia ---- 332
  Mineral food ---- 332
  Coal-mine dusting ---- 332
  Magnesium metal ---- 333
  Insecticides, fungicides, and disinfectants ---- 333
  Leather ---- 333
  Sewage and trade-waste treatment ---- 333
  Poultry grit ---- 334
  Petroleum refining ---- 334
  Miscellaneous processing industries ---- 334

INTRODUCTION

Limestone (which consists essentially of calcium carbonate) and dolomite (calcium magnesium carbonate) occur widely in the United States. Their presence is of vast economic importance, because they are used much more extensively than any other form of rock. In 1945, limestone (which, broadly, includes dolomite) was quarried in every state except Delaware, New Hampshire, North Dakota, and Rhode Island; and also in Hawaii and Puerto Rico. Total production (including that used in cement and lime manufacture) exceeded 151,700,000 tons, or 79 percent of the quantity of all kinds of stone sold or used during that year.

Important well-known uses of limestone are as concrete aggregate, road material, railroad ballast, for liming the land, for cement manufacture, as riprap for shore protection, harbor work, and spillways at dams, and as building stone. None of these uses, however, are considered herein. The purpose of this paper is to discuss the industrial and chemical uses that are less widely known and yet are of tremendous importance in a great variety of processing industries. Important examples are dolomite as a refractory furnace lining and limestone as a fluxing agent in blast furnaces, and as a raw material employed in sugar, paper, glass, and alkali manufacture.

---

* Reprinted from Bureau of Mines Information Circular 7402.

** Chief, Nonmetal Economics Division, Bureau of Mines.

† Nonmetal Economics Division, Bureau of Mines.

Table 1. Quantity of limestone and the limestone equivalent of lime sold or used by producers in the United States for the principal chemical and processing applications, 1921-45, in short tons

Year	Metallurgy[1] (flux)	Alkali	Refractory (dolomite)	Paper[2]	Calcium carbide[3]	Glass	Water purification	Fertilizer filler	Sugar
1921	10,983,150	1,757,790	294,810	592,170	266,450	206,670	148,400	----------	595,290
1922	19,091,870	2,526,500	844,320	769,890	256,190	290,440	174,860	----------	404,220
1923	26,308,180	3,393,980	921,170	829,360	287,790	355,260	184 810	----------	500 620
1924	20,356,780	2,976,820	966,330	738,480	342,510	322,900	227,150	----------	652,350
1925	23,662,880	3,611,160	1,200,000	863,070	341,370	470,180	231,550	(4)	509,760
1926	24,666,170	3,609,590	1,284,730	1,049,100	402,020	494,810	278,960	(4)	447,680
1927	22,472,950	3,887,710	1,182,990	1,148,220	371,030	405,200	248,420	(4)	515,970
1928	24,102,590	4,245,100	1,420,370	1,013,720	347,800	433,580	291,510	(4)	532,420
1929	25,494,260	5,047,260	1,492,460	1,095,910	401,510	407,940	312,230	[5]3,910	529,510
1930	17,852,730	4,461,430	1,156,830	1,006,230	417,410	350,000	323,610	[5]12,240	452,150
1931	10,255,500	3,368,450	756,040	767,800	211,990	277,520	320,770	(4)	490,010
1932	4,286,210	3,227,650	343,710	671,550	233,720	211,000	285,190	(4)	553 240
1933	[5]8,514,490	4,213,050	720,160	805,900	164,230	364,990	349,390	----------	642,730
1934	[5]9,899,690	3,869,450	949,920	849,760	377,210	313,680	367,160	----------	520,960
1935	13,097,180	4,127,250	1,232,380	877 150	392 410	434,360	407,680	39,590	501,210
1936	18,870,030	4,430,680	1,594,820	1,049,610	497,620	492,400	438,800	[5]38,380	575,980
1937	22,700,880	4,888,030	1,812,310	1,218,270	691,750	609,650	424,430	74,400	609 040
1938	10,679,170	3,658,790	997,180	1,027,480	478,360	424,240	372,420	121,130	664,920
1939	18,769,270	4,671,630	2,168,050	1,231,070	445,330	537,040	502,390	116,080	659,390
1940	24,855,340	4,878,970	2,593,770	1,467,440	658,970	636,810	532,180	233,990	596,740
1941	30,166,320	[5]5,888,260	3,119,960	1,716,060	741,080	754,800	638,490	[5]301,650	670,790
1942	33,412,440	6,365,120	3,812,800	1,648,080	835,640	815,240	671,750	226,910	680,830
1943	35,371,590	6,883,210	3,659,010	1,471,630	1,237,100	921,260	[5]791,660	276,410	389,530
1944	34,536,200	6,998,180	3,656,630	1,440,270	1,463,480	934,310	[5]749,580	373,970	299,990
1945	30,524,920	[5]7,076,330	3,401,760	1,374,650	1,279,400	998,320	[5]804,320	401,160	389,480

Table 1. Quantity of limestone and the limestone equivalent of lime sold or used by producers in the United States for the principal chemical and processing applications, 1921-45, in short tons—Continued

Year	Limestone whiting[6]	Magnesia	Mineral food (stock feed)	Coal-mine dusting	Insecticides, fungicides, and disinfectants	Tanneries	Sewage and trade-wastes treatment	Miscellaneous filler (not whiting substitute)[7]
1921	29,560	[5]32,050	----------	----------	15,960	95,680	6,840	----------
1922	66,200	[5]53,170	----------	----------	19,370	85,960	8,240	----------
1923	81,310	[5]116,410	(4)	----------	[5]21,940	107,810	2,950	----------
1924	66,910	[5]98,160	(4)	3,020	24,250	106,700	14,790	----------
1925	82,290	[5]98,980	6,080	15,550	36,570	125,870	18,610	----------
1926	95,650	[5]72,850	13,030	26,620	39,980	133,070	5,460	----------
1927	124,840	[5]69,940	[5]30,470	28,410	[5]44,310	127,330	4,830	----------
1928	95,400	[5]94,200	[5]39,460	54,460	[5]38,540	128,930	5,710	----------
1929	125,430	[5]84,740	[5]25,270	34,650	[5]53,780	134,090	9,070	----------
1930	119,350	[5]111,740	[5]30,350	47,750	[5]51,240	113,050	5,800	----------
1931	73,420	[5]80,820	[5]21,880	38,040	[5]42,390	109,210	23,050	----------
1932	76,020	[5]62,930	[5]23,060	25,400	[5]44,380	91,890	(4)	15,070
1933	93,070	92,820	26,860	34,080	[5]44,860	141,320	(4)	13,940
1934	97,340	92,690	35,870	43,000	[5]58,650	125,490	(4)	13,850
1935	[5]147,910	106,740	42,980	52,660	[5]76,860	142,760	(4)	55,850
1936	179,110	137,560	53,830	53,480	[5]95,200	145,700	8,380	78,490
1937	194,080	116,910	67,230	64,610	91,930	123,090	7,950	20,890
1938	145,170	100,200	65,570	50,890	87,840	119,710	17,390	61,970
1939	175,460	151,440	68,580	68,260	93,820	140,890	33,840	84,910
1940	207,910	171,530	93,160	99,300	109,260	144,830	38,320	93,670
1941	[5]417,750	208,180	115,400	136,180	163,910	186,310	76,510	68,980
1942	[5]326,930	166,920	169,880	193,260	132,660	157,490	51,520	107,760
1943	296,370	[8]269,430	[5]293,490	194,360	150,250	138,440	35,320	178,250
1944	352,490	[8]275,210	265,590	196,470	158,760	165,450	128,380	236,720
1945	343,220	[8]342,830	313,180	216,160	165,010	162,430	142,990	138,750

Table 1. Quantity of limestone and the limestone equivalent of lime sold or used by producers in the United States for the principal chemical and processing applications, 1921-45, in short tons—Continued

Year	Poultry grit	Petroleum refining	Chromates and bichromates	Coke and gas (gas purification and plant by-products)	Bleach, liquid and powder[9]	Paints and varnish	Explosives	Brick, silica (refractory)	Brick, sand-lime and slag	Filter beds
1921	11,780	770	----------	19,300	25,100	[5]2,890	----------	14,250	10,930	(4)
1922	10,790	1,870	----------	28,680	41,960	[5]5,010	(4)	23,410	57,220	(4)
1923	13,080	2,040	----------	23,780	56,400	11,660	(4)	27,990	29,710	(4)
1924	6,780	(4)	----------	50,280	68,260	9,510	(4)	20,990	53,100	(4)
1925	17,050	(4)	(4)	58,000	36,390	7,790	(4)	51,800	50,290	(4)
1926	17,450	(4)	(4)	53,360	30,890	4,310	(4)	29,760	79,640	(4)
1927	33,350	14,200	(4)	59,980	32,060	10,100	----------	31,280	86,130	271,800
1928	18,110	(4)	(4)	62,020	67,850	10,030	----------	31,470	95,050	41,230
1929	34,600	(4)	(4)	68,450	51,800	10,220	----------	36,780	85,080	72,870
1930	45,920	(4)	(4)	50,430	41,350	8,220	(4)	29,860	59,010	30,860
1931	31,320	(4)	(4)	45,170	42,890	12,190	(4)	17,750	35,060	56,100
1932	14,960	(4)	(4)	34,450	38,750	19,590	(4)	5,940	27,050	81,600
1933	24,550	(4)	(4)	45,530	[5]31,130	13,600	(4)	17,490	8,700	(4)
1934	26,320	(4)	(4)	46,890	[5]26,560	23,640	(4)	14,790	16,890	93,020
1935	30,290	(4)	(4)	41,830	21,480	29,410	(4)	18,230	22,800	49,860
1936	22,820	25,000	16,530	52,210	25,590	35,590	(4)	[10]25,730	[10]36,820	98,690
1937	27,360	20,320	22,430	43,980	18,280	54,480	(4)	[10]25,770	[10]41,490	34,970
1938	31,260	13,830	27,650	29,690	33,690	25,180	(4)	[10]11,470	[10]28,830	142,050
1939	39,010	56,000	(4)	26,460	21,150	55,070	(4)	21,890	50,730	105,850
1940	38,910	58,690	(4)	28,280	21,220	65,250	(4)	30,710	39,240	61,290
1941	62,070	69,390	36,550	44,020	29,370	92,750	(4)	49,930	43,010	32,950
1942	62,620	61,890	41,080	35,260	26,320	29,180	(4)	35,010	41,100	66,310
1943	119,080	57,460	45,940	61,090	23,240	17,300	20,190	30,410	11,960	36,260
1944	130,450	68,250	69,350	54,780	23,940	22,410	42,430	31,860	6,240	20,880
1945	114,670	106,350	72,500	62,350	49,420	38,630	31,060	30,660	25,280	20,920

Table 1. Quantity of limestone and the limestone equivalent of lime sold or used by producers in the United States for the principal chemical and processing applications, 1921-45, in short tons—Continued

Year	Glue	Medicines and drugs	Creameries and dairies	Rubber manufacture	Soap and fat	Gelatin	Miscellaneous food products[11]	Grease, lubricating	Salt refining	Wood distillation
1921	8,030	(4)	1,470	1,450	[5]28,500	2,570	[5]2,230	19,170	2,140	4,940
1922	9,890	----------	450	3,850	[5]39,230	----------	[5]450	7,950	2,560	11,930
1923	20,970	----------	780	1,530	[5]48,880	(4)	[5]1,320	12,510	1,940	17,540
1924	12,940	(4)	3,090	3,260	[5]71,690	(4)	[5]370	----------	2,960	11,740
1925	23,480	----------	4,170	7,140	[5]40,850	(4)	[5]830	----------	2,200	5,610
1926	22,240	----------	5,440	7,080	[5]41,430	(4)	[5]1,050	----------	3,440	24,450
1927	15,730	----------	(4)	8,380	[5]58,770	(4)	(4)	----------	2,420	23,360
1928	16,930	(4)	(4)	6,720	[5]85,760	(4)	(4)	----------	4,850	7,800
1929	19,770	(4)	(4)	9,580	[5]103,120	(4)	(4)	----------	4,370	8,890
1930	14,390	(4)	(4)	8,400	[5]93,830	(4)	(4)	----------	7,500	5,580
1931	12,780	(4)	(4)	5,800	[5]59,150	(4)	(4)	----------	6,070	2,200
1932	6,530	(4)	(4)	4,620	64,450	(4)	[5]13,770	(4)	3,010	3,510
1933	6,970	----------	(4)	4,120	58,000	4,230	[5]18,380	(4)	[5]10,280	3,120
1934	12,460	----------	(4)	5,550	45,850	2,300	[5]17,270	(4)	[5]14,320	6,920
1935	14,430	----------	(4)	5,250	58,220	8,390	[5]14,710	(4)	[5]11,880	8,530
1936	17,790	----------	(4)	6,910	50,400	10,340	[5]26,470	----------	12,490	8,870
1937	15,760	----------	(4)	3,460	55,270	9,980	[5]21,330	(4)	10,740	12,060
1938	12,910	----------	(4)	2,660	39,910	11,850	[5]12,400	(4)	8,630	2,020
1939	13,860	(4)	1,360	2,710	19,120	13,170	13,910	6,150	13,120	2,950
1940	16,110	----------	510	3,760	13,710	8,170	5,770	3,230	10,760	4,910
1941	24,010	(4)	2,340	6,120	(4)	9,690	1,770	8,000	3,910	5,110
1942	15,770	12,040	2,850	2,760	13,350	14,450	17,900	9,990	8,230	5,800
1943	18,930	9,840	7,330	4,080	11,490	10,550	9,070	14,780	9,300	3,700
1944	18,260	13,410	13,220	11,270	12,070	13,670	11,850	2,590	11,000	1,490
1945	18,300	15,790	14,600	14,340	10,440	10,050	9,170	4,140	3,770	2,530

Table 1. Quantity of limestone and the limestone equivalent of lime sold or used by producers in the United States for the principal chemical and processing applications, 1921-45, in short tons—Continued

Year	Acetic acid, carbolic acid, and carbonic acid	Acid neutralization	Alcohol	Calcium acetate	Calcium carbonate (precipitated)	Polishing compounds	Textiles	Tobacco
1921	[5]125,640	(4)	(4)	7,450		(4)	(4)	
1922	30,840		(4)	27,000	(4)	(4)		
1923	46,900	4,750	(4)	25,670		(4)	(4)	
1924	38,390	(4)	18,360	8,250			4,770	
1925	46,950	(4)	1,360	21,050		(4)	2,060	
1926	(4)	(4)	6,590	14,260		(4)	2,270	(4)
1927	[5]8,860	(4)	4,400	19,240		(4)	2,260	
1928	[5]4,690	(4)	4,600	3,290		(4)	2,920	
1929	[5]4,560	(4)	620	42,270		(4)	5,710	
1930	[5]2,290	(4)	4,320	6,210		(4)	5,560	
1931	[5]2,670	(4)	4,340	5,000		(4)	2,480	(4)
1932	(4)	(4)	4,030	6,000		(4)	1,470	(4)
1933	(4)	[5]11,830	(4)	12,510		2,280		6,150
1934	(4)	[5]17,270	(4)	10,150		4,850	(4)	6,780
1935	(4)	[5]8,690	(4)	7,000		6,210	(4)	7,420
1936	(4)	[5]6,220	(4)	6,110		7,010	(4)	7,830
1937	(4)	[5]6,870	(4)	(4)	(4)	7,100	(4)	
1938	(4)	[5]10,150	(4)	(4)	(4)	4,610	(4)	
1939	(4)	(4)	1,890		11,200	6,990	2,510	9,050
1940		(4)	5,060		12,070	12,690	3,400	10,750
1941		[5]3,480	(4)		11,580	7,840	2,180	(4)
1942		[5]10,360	(4)		(4)	1,520	1,740	13,720
1943		[5]35,530	(4)		(4)	(4)	990	(4)
1944		(4)	(4)		(4)	(4)	(4)	(4)
1945		(4)	(4)		(4)	(4)	(4)	(4)

---

[1] Includes flux, ore concentration (flotation, cyanidation, bauxite purification, and magnesium manufacture), wire drawing, and other metallurgical uses.

[2] Includes bleach used in paper mills.

[3] 1939-45: Calcium carbide and cyanamide.

[4] Bureau of Mines not at liberty to publish figures. To avoid disclosing confidential information, the quantity is included under "Other uses" or "Undistributed" in the use tables appearing in the Stone or Lime chapters of the Minerals Yearbook for the respective year.

[5] Incomplete data. To avoid disclosing confidential information, the lime or limestone entering into some products is included under "Other uses" or "Undistributed" in the use tables appearing in the Stone or Lime chapters of the Minerals Yearbook for the respective year.

[6] Includes filler for calcimine, caulking compounds, chewing gum, cosmetics, crayons, explosives, flavoring extracts, foundry facing powder, graphite, leather goods, linoleum, paint, paper, phonograph records, plastics, pottery, putty, roofing, rubber, sealing wax, tanning, tile, tooth paste, tooth powder, wire coating, and unspecified uses.

[7] Does not include asphalt filler or fertilizer filler.

[8] Includes dolomite for refractory magnesia.

[9] Excludes bleach used in paper mills.

[10] Slag brick included with silica brick.

[11] Includes chocolate, cocoa, fruit juices, phosphate baking powders, and unspecified food products.

PRIOR REPORT

In May 1941, the Bureau issued a report[1] that described these uses in some detail. As new and important developments have taken place during the ensuing years, a revision and representation of the salient features of these uses seem desirable. Asphalt filler and mineral wool uses included in the earlier report are omitted from this paper because they are identified more closely with the highway and building industries, respectively, than with the industrial applications.

COMPOSITION

Limestone, a sedimentary rock of wide occurrence in nature, consists essentially of calcium carbonate ($CaCO_3$)—the mineral calcite—or of a mixture of the carbonates of calcium and magnesium. When 10 percent or more is magnesium carbonate ($MgCO_3$), the rock is termed "magnesium" limestone or "dolomitic" limestone; if the amount approaches 45 percent, the rock is composed essentially of the double carbonate of lime and magnesium ($CaCO_3 \cdot MgCO_3$)—the mineral dolomite. The principal impurities in limestone are sand, clay, and iron oxide. Marble is similar in composition and can be used in the same processes as limestone.

LIME INCLUDED WITH LIMESTONE

Lime is made by calcining limestone. Lime manufacture may, therefore, be regarded as an important branch of the limestone industry, so important, in fact, that the Bureau of Mines includes each year a chapter on Lime in the Minerals Yearbook which is separate from the chapter on Stone. To obtain a complete picture of the use of limestone in industry, consideration must be given not only to the limestone sold to or used directly in industry, but also to that which is first calcined into lime and thereafter employed in the chemical and processing industries. The overall statistics according to use presented herein include both raw limestone and the limestone equivalent of lime so employed. The limestone equivalent of lime is determined on the basis of the approximate requirement of 2 tons of limestone to make 1 ton of lime.

STATISTICAL HISTORY OF PRINCIPAL INDUSTRIAL USES

Table 1 presents a 25-year history of the more important uses of limestone in industry. For the major uses, the history is fairly complete and enables one to study the trends in use over the past quarter of a century. For some of the smaller uses, the history is more fragmentary, but even scattered figures are useful in evaluating the past, present, and possible future importance of these uses.

INDUSTRIAL APPLICATIONS

Table 2 presents the production of limestone applied in the chemical and processing industries for the most recent year for which statistics are now available (1945), according to use, showing the percentage of the total applied to each use. Of the 151,700,000 tons of limestone sold or used in 1945 for all purposes, 49,800,000, or approximately one-third of the total, was used in the chemical and processing industries. The first seven items given in this table account for 93 percent of the total stone used in the industries enumerated; the remaining 7 percent, roughly 3½ million tons, is divided among many industries. The quantities used by

---

[1] Bowles, Oliver, and Jensen, Mabel S., Limestone and dolomite in the chemical and processing industries: U. S. Bur. Mines Inf. Circ. 7169, 15 pp., 1941.

Table 2. Limestone and the limestone equivalent of lime sold or used by producers in the United States in chemical and processing applications in 1945, by uses

Use	Short tons	Percent of total	Use	Short tons	Percent of total
Metallurgical (flux)[1]	30,524,920	62.4	Coke and gas (gas purification and plant byproducts)	62,350	0.1
Alkali	[2]7,076,330	14.5	Bleach, liquid and powder[8]	49,420	0.1
Refractory (dolomite)	3,401,760	7.0	Paints and varnish	38,630	(9)
Paper[3]	1,374,650	2.8	Explosives	31,060	(9)
Calcium carbide and cyanamide	1,279,400	2.6	Brick, silica (refractory)	30,660	(9)
Glass	998,320	2.0	Brick, sand-lime and slag	25,280	(9)
Water purification	[4]804,320	1.7	Filter beds	20,920	(9)
Fertilizer filler	401,160	0.8	Glue	18,300	(9)
Sugar	389,480	0.8	Medicines and drugs	15,790	(9)
Limestone whiting[5]	343,220	0.7	Creameries and dairies	14,600	(9)
Magnesia[6]	342,830	0.7	Rubber manufacture	14,340	(9)
Mineral food	313,180	0.6	Soap and fat	10,440	(9)
Coal-mine dusting	216,160	0.5	Gelatin	10,050	(9)
Insecticides, fungicides, and disinfectants	165,010	0.3	Miscellaneous food products[10]	9,170	(9)
Tanneries	162,430	0.3	Grease, lubricating	4,140	(9)
Sewage and trade-wastes treatment	142,990	0.3	Salt refining	3,770	(9)
Miscellaneous filler (not whiting substitute)[7]	138,750	0.3	Wood distillation	2,530	(9)
Poultry grit	114,670	0.2	Other uses[11]	185,830	0.4
Petroleum refining	106,350	0.2			
Chromates and bichromates	72,500	0.2		48,915,710	100.0
			Unspecified uses[12]	884,910	--------
			Total	49,800,620	--------

---

[1] Includes flux, ore concentration (flotation, cyanidation, bauxite purification, and magnesium manufacture), wire drawing, and other metallurgical uses.

[2] Limestone only. To avoid disclosing confidential information, limestone equivalent of lime sales is included under "Other uses."

[3] Includes bleach used in paper mills.

[4] Limestone equivalent of lime only. To avoid disclosing confidential information, limestone sales are included under "Other uses."

[5] Includes filler for calcimine caulking compounds. crayons, explosives. leather goods, linoleum, paint, paper, phonograph records, plastics, pottery, putty, roofing, rubber, tanning, tooth paste, and wire coating.

[6] Includes dolomite for refractory magnesia.

[7] Does not include asphalt filler or fertilizer filler.

[8] Excludes bleach used in paper mills.

[9] Less than 0.1 percent.

[10] Includes chocolate, cocoa, fruit juices, phosphate baking powders, and unspecified food products.

[11] Includes acid neutralization, alcohol, calcium carbonate (precipitated), carbon dioxide, miscellaneous chemicals, magnesium metal, oil-well drilling, polishing compounds, rayon, retarder, rice milling, sulfur, textiles, tobacco, and wool pullers.

[12] Includes some limestone used for other than chemical and processing applications.

them are relatively so small that they would appear to be of minor consequence. However, the importance of limestone to industry cannot be measured merely by its tonnage or money value, because for many industries limestone is an essential raw material for which it is impractical to use any substitute.

The Bureau of Mines is not at liberty to publish figures where the number of producers is so small that confidential data would be revealed. Therefore, it has been necessary to omit a number of uses from the table. The minor uses, enumerated in footnote 11 of the table, consumed 185,830 short tons of limestone and limestone equivalent of lime in 1945.

The balance of the report following this table comprises a discussion of the various uses of limestone in industry, the specifications for each use, and the principal localities from which limestone for each major use is obtained.

Metallurgy (Flux)

Enormous quantities of lime and limestone are consumed annually as fluxing material in blast furnaces, open-hearth and electric steel plants, and to a smaller degree in nonferrous metallurgy. Most iron ores carry alumina and silica as impurities, and the addition of a basic flux such as limestone is necessary to form a slag with them. The limestone also removes sulfur, which is an impurity in iron and steel. It is evident, therefore, that limestone, to be efficient as a flux, should be relatively free from alumina and silica. If more than small percentages of these elements are present, the stone is less effective, increases slag volume and fuel consumption, and slows production.

The element of cost, however, is an important factor in the purity of stone used. As silica and alumina are not classed as harmful impurities but simply as diluents, it may be more economical to use a conveniently located low-cost stone relatively high in these impurities than to use a much purer stone that must be shipped in from more distant points with consequent higher delivered cost.

In 1945, fluxing stone was reported from 34 states, and sales totaled 27,639,520 short tons, or 18 percent of the total limestone sold or used for all purposes. The largest producing states were Michigan, with 31 percent of the total output; Pennsylvania, 30 percent; Ohio, 18 percent; West Virginia, 7 percent; and Alabama, 6 percent. Limestone used as flux comprised over half of the total limestone tonnage reported in each of the above states, with the exception of Ohio. Seventy-nine percent of all flux sold was used in blast furnaces; 18 percent in open-hearth steel plants; 2 percent in copper, gold, lead, zinc, and unspecified smelters; and 1 percent in foundries and in cupola and electric furnaces.

Lime is also used extensively as a metallurgical flux, particularly in open-hearth steel plants. Open hearths and electric furnaces consumed 1,064,005 tons and nonferrous smelters 7,442 tons in 1945. The chief producing states, in order of importance, were West Virginia, Pennsylvania, Alabama, Missouri, Ohio, and Illinois.

Alkali

In the manufacture of soda ash by the ammonia-soda process, about 1¼ tons of high-calcium limestone are used for each ton of soda ash produced. The stone is calcined at the chemical plant, and both the lime and carbon dioxide gas are used. Stone ranging from 1 to 6 inches in diameter is desired.

Limestone for alkali manufacture should be pure enough to yield, upon calcination, a product containing not less than 85 percent available lime as determined by the modified Scaife method.[2] Also, the resulting lime should contain not more than 3 percent magnesium oxide.

A large proportion of the limestone produced for use in alkali works is captive tonnage; that is, it is produced by the industry that uses it. For a number of years, Michigan and New York were the only states producing high-calcium stone for this use; but in 1945, 12 companies operating 15 plants reported tonnage from eight states. Alpena, Presque Isle, and Wayne Counties, Michigan, with an output of 4,030,730 short tons in 1945, or 57 percent of the total of 7,076,330, constitute the area of largest production in the United States. Other producing centers, according to rank of importance in output are Erie and Onondago Counties, New York; Calcasieu and Winn Parishes, Louisiana; Smyth County, Virginia; Bexar and Comal Counties, Texas; Summit County, Ohio; El Dorado and San Bernardino Counties, California; and Shelby County, Alabama. Relatively small quantities of lime are sold for alkali manufacture.

Refractories

Dolomite and high-magnesium limestone are used widely as substitutes for magnesite refractories in basic open-hearth steel and other metallurgical furnaces. Dead-burned material in various forms is commonly used, although raw dolomite may be employed for repair work. The refractory stone shown in table 2 includes raw stone and the raw-stone equivalent of the dead-burned product.

Where dead-burned dolomite is used as a substitute for dead-burned magnesite in basic furnace bottoms, the raw stone should contain not more than 1 percent of silica, not more than 1.5 percent of combined iron oxide and alumina, and at least 35 percent of magnesium carbonate. The specifications for raw dolomite for patching purposes need not be quite so rigid. Sales of raw stone (1,027,090 short tons) in 1945 were reported by 12 companies operating 14 plants in the following 11 states: Colorado, 1; Illinois, 3; Indiana, 1; Massachusetts, 1; Michigan, 1; Nevada, 1; New York, 1; Ohio, 1; Pennsylvania, 2; West Virginia, 1; and Wisconsin, 1. Pennsylvania, West Virginia, Illinois, and Colorado, in order of importance, produced 95 percent of the total.

Sales of dead-burned dolomite amounted to 1,187,334 short tons (limestone equivalent approximately 2,374,670 short tons) in 1945 and were reported by 14 companies operating 17 plants in the following eight states: Alabama, 1; California, 1; Colorado, 1; Illinois, 2; Missouri, 1; Ohio, 7; Pennsylvania, 2; and West Virginia, 2. Ohio, Pennsylvania, West Virginia, and Illinois, in order of importance, produced 89 percent of the total.

Paper

Both lime and limestone are used in the paper industry in the preparation of the cooking liquor. By digesting the wood with an acid liquor, all the constituents of the wood chips except cellulose are dissolved and removed. The cooking liquor is produced by the chemical reaction between sulfur dioxide and lime.

---

[2] For details of this method, see Proc., Amer. Soc. Testing Materials, vol. 25, Part I (1925), p. 627; or Ind. and Eng. Chem., vol. 20 (1928), pp. 1355-56; or Recommended specification for quicklime and hydrated lime for use in the purification of water: U. S. Bur. Standards Circ. 231, 1925.

For the milk-of-lime method of making sulfite pulp, a high-magnesium or dolomitic lime is preferred. However, if the Jennsen tower system is used, limestone rather than lime is employed, and a high-calcium stone generally gives better service than a high-magnesium stone.

For the soda-pulp and sulfate-pulp processes, a high-calcium lime containing less than 2 percent magnesia is desired. Lime having as much as 7 percent iron oxides, silica, and alumina has been used, but in general the purer the lime the better.

An Interdepartmental Conference established in 1920 a specification for lime to be used in cooking rags for the manufacture of paper, which required that quicklime for such use should contain not less than 95 percent calcium oxide, not more than 2 percent magnesium oxide, not more than 2 percent of the oxides of silicon, iron, aluminum, and other insoluble matter, and not more than 2 percent carbon dioxide. For hydrated lime, these limiting percentages were, respectively, 72, 1.6, 1.6, and 1.6.

Limestone for use in the manufacture of chemical pulp was quarried in 11 states, in order of importance as follows: Washington, Michigan, Pennsylvania, Texas, Maine, Oregon, Virginia, Vermont, Ohio, Wisconsin, and Tennessee. Sales totaled 352,990 short tons in 1945.

Lime sold to paper mills in 1945 totaled 510,832 short tons. The leading states in sales of lime for this use, in order of importance, were Alabama, Pennsylvania, Tennessee, Michigan, Ohio, and Minnesota.

In the soda process of preparing chemical pulp, an important re-use of lime has been developed. The soda liquor, which is separated from the pulp, is concentrated and evaporated to dryness, and the ash is leached for its soda content. It becomes carbonated during the process and is converted into caustic soda, ready for reuse by treating it with lime. The reaction is as follows: $Na_2CO_3 + Ca\ (OH)_2 = 2NaOH + CaCO_3$. The calcium carbonate settles out as a sludge, which is calcined into lime and is then available for reuse.

It is obvious from the above statement that the quantity of limestone sold to the paper industry is not a true measure of the quantity required per ton of pulp prepared, because a considerable quantity of the limestone is used repeatedly.

Calcium Carbide

Calcium carbide and calcium cyanamide are products of the electric furnace. Calcium carbide is formed when a charge of lime and coke, mixed in the proportion of 60 and 40 percent, respectively, is heated to 2,000° C. Approximately 2 tons of limestone or 1 ton of lime is required for each ton of calcium carbide manufacture. Calcium cyanamide is derived from the carbide by treating it with nitrogen. No cyanamide has been made in the United States in recent years. Calcium carbide is important chiefly because, with water, it forms acetylene, used for lighting and for the steel-cutting and welding torch. One of the newer uses is in the manufacture of synthetic rubber. Calcium cyanamide is a nitrogenous fertilizer.

The use of calcium carbide increased greatly during the war, partly because of the very extensive use of acetylene welding and partly because of the expanded program of synthetic rubber manufacture.

A very pure, high-calcium limestone must be employed in the manufacture of these products, especially if the carbide is to be used for acetylene. The limestone should contain not more than 0.01 percent phosphorus pentoxide, because when phosphates are present undesirable phosphides are formed. The stone also must contain not more than 0.5 percent MgO, because magnesium does not form a carbide, and the presence of its oxide in the charge makes the electrolytic process less efficient. Combined alumina and iron oxide should not exceed 0.5 percent, silica not more than 1.2 percent, and sulfur not more than a trace.

According to compilations made by the Federal Power Commission, 13 plants were producing calcium carbide in the United States during recent years. Plant locations are as follows: Alabama 2, Iowa 2, Kansas 1, Kentucky 1, Michigan 1, New York 1, Ohio 2, Oregon 2, and Virginia 1. One of the Alabama plants (the T. V. A. plant at Wilson Dam) discontinued operation in December 1945.

In 1945, four limestone companies reported production of 549,510 short tons of raw stone sold for the manufacture of calcium carbide: one in Presque Isle County, Michigan; one in Madison County, Alabama; and one each in Giles and Wythe Counties, Virginia.

Lime for calcium carbide manufacture originated in the following states in order of importance: Missouri, Pennsylvania, Wisconsin, Indiana, Michigan, and Washington. Sales in 1945 (364,944 short tons) were considerably smaller than in 1944, chiefly because of the cut-back in acetylene welding.

Glass

In the manufacture of glass, either lime or limestone of high calcium or high magnesium content may be used. High-calcium limestone is used in making bottle and window glass, whereas dolomitic stone is used for special glasses. Uniform stone must be used for each type of glass in order that the product may have constant chemical and physical properties. Common glass is made from the fused mixture of alkali, lime or limestone (limestone may constitute as much as 30 percent of some glass batches), and silica. Limestone for use in clear, colorless glass products must contain a very low percentage of iron oxide. Silica in moderate quantities is not detrimental, but the sulfur and phosphorus content should be low.

Production of limestone for glass making was confined to 13 states, with Ohio, the leading state, reporting 175,300 short tons, or 31 percent of the total output of 556,610 short tons in 1945. Other leading states in the production of limestone for glass making were, in order of production, Missouri, Pennsylvania, Illinois, California, Indiana, Arkansas, Tennessee, Texas, and Washington, with small tonnages reported from Connecticut, Michigan, and Vermont.

In addition to the limestone recorded above, the glass industry used 220,853 short tons of lime in 1945. Ohio produced by far the largest part of the lime so used.

Water Purification

Lime is used extensively for water treatment, particularly for purification and softening of municipal water supplies and for correcting the scale-forming hardness of boiler water.

Either quicklime or hydrated lime may be used for these purposes. Limestone as the raw material for making lime to be so used must be reasonably free from alumina, silica, and other impurities. The purity of the stone will, of course, be governed by the requirements of the lime. The specifications of lime for water treatment as recommended by the

American Water Works Association are not framed on the basis of percentage of impurities permissible but on the percentage of available lime, which has been discussed previously under "Alkali." The specifications require that quicklime for such use contain at least 85 percent available lime (CaO) and hydrated lime at least 90 percent available calcium hydroxide [$Ca(OH)_2$].

Water purification has become an important use for lime. Sales for such use amounted to 402,158 short tons in 1945. The leading states, in order of production, were Missouri, Pennsylvania, Illinois, Texas, Minnesota, and Ohio.

Fertilizer Filler

The use of limestone as a fertilizer filler has increased greatly during recent years. In 1936 only 38,380 tons were so used. The quantity had increased to over 300,000 tons in 1941 and to 401,160 tons in 1945. The filler reduces the caking of fertilizers and serves as a soil conditioner. Both dolomite and high-calcium limestone are satisfactory for this use.

In 1945, stone for this purpose was reported from 11 states. Virginia, which produced 47 percent of the total, is followed, in rank of importance, by Georgia, Pennsylvania, Maryland, Ohio, California, Illinois, Arkansas, Connecticut, Washington, and Massachusetts.

Sugar

Lime is an indispensable material in the manufacture of beet and cane sugar. Its function is to precipitate impurities from the juices or syrup or to precipitate the sugar from impure solutions. Only high-calcium limestone, containing about 97 percent calcium carbonate and free from impurities that would impart a taste, is desired. Limestone is used in refining beet sugar by the carbonization process. The limestone is burned to lime, and both the lime and carbon dioxide gas are used. Because carbon dioxide as well as lime is necessary to beet-sugar refining, the raw tone is burned at the refinery. For every pound of beet sugar produced, a little more than half a pound of limestone is used in the manufacturing process. Cane sugar refining companies buy burned lime because carbon dioxide is not necessary in the refining process.

The reuse of lime is also being practiced in the sugar-refining industry. The Steffen process of refining sugar requires finely powdered quicklime, which precipitates sucrose from an aqueous solution of beet molasses. After the reaction is complete, the addition of carbon dioxide converts the lime into calcium carbonate, which precipitates and is removed by filtering. Filter cake is recalcined less extensively in the sugar than in the paper industry, but recently a continuous process has been perfected whereby recalcination probably will become a more important factor.

The states producing the greatest quantities of limestone for use in sugar manufacture in 1945 were Wyoming, Michigan, and California, which together supplied 55 percent of the total sales of 340,310 short tons. Other producing states were, in order of importance, Colorado, Montana, Utah, Nevada, Nebraska, Iowa, Missouri, South Dakota, and Idaho. A small tonnage was reported in Puerto Rico.

Lime for use in sugar refining, which totaled 24,584 short tons in 1945, was reported chiefly from Hawaii, Michigan, Arkansas, Pennsylvania, Puerto Rico, and Louisiana.

Whiting

The Bureau of Mines considers whiting as divisible into three classes: limestone and marble whiting, consisting of finely pulverized limestone (or crystalline limestone) of a quality suitable for use as a filler or pigment; chalk whiting, a material prepared from chalk; and precipitated whiting, material prepared as a precipitate from some soluble calcium salt or from a milk of lime suspension that has been recarbonated.

Very few deposits of true chalk suitable for the manufacture of whiting have been exploited in the United States. Virtually all of the chalk whiting used in the United States is imported or is manufactured from imported crude chalk. The use of limestone and marble whiting from domestic sources is becoming increasingly important. The products in which it is used are indicated in footnote 5 to table 2.

Production of ground limestone for whiting was reported in 1945 from 18 states. Ohio, Nebraska, Vermont, Tennessee, and Illinois produced 49 percent of the total stone (343,220 short tons) used for whiting applications. Other states, in rank of importance, were Alabama, New York, Pennsylvania, California, Indiana, Massachusetts, Michigan, Maryland, Oregon, New Jersey, Connecticut, Wisconsin, and Missouri.

Magnesia

Large quantities of dolomite are consumed annually for the manufacture of basic magnesium carbonate (also called technical carbonate, block magnesia, and magnesia alba), which finds its greatest outlet in the manufacture of pipe and boiler covering and general heat insulation. Magnesia recovered from dolomite is also used for making periclase refractories. Sales of dolomite for these uses in 1945 were reported by eight companies operating plants in the following states, in order of importance: California, 2; Pennsylvania, 3; Ohio, 2; and Maryland, 1. Sales totaled 295,540 short tons.

Relatively small quantities of lime are used for magnesia manufacture.

Mineral Food

Calcium is important to the success of livestock farming because it serves as a bone builder, is necessary in the proper functioning of the nervous system, and also acts as a neutralizer in the digestive tract. According to the Kansas State Agricultural College, one-tenth pound of limestone should be consumed each day per head of livestock. A satisfactory limestone for stock food should contain at least 95 percent calcium carbonate, no fluorine, and very little magnesium. The stone must be ground almost as fine as wheat flour.

Production of limestone for mineral food was so small that before 1925 separate figures were not given in Bureau of Mines reports. Production had increased to 68,580 tons by 1939 and to 291,580 tons in 1945.

Production of limestone for mineral food in 1945 was reported from 13 states. Missouri and Illinois produced 49 percent of the total, followed, in rank of importance, by Nebraska, Iowa, Pennsylvania, Ohio, Arkansas, California, Kansas, Virginia, Texas, Vermont, and Washington. Small quantities of lime are also used as mineral food.

Coal-Mine Dusting

Several hundred operators of bituminous coal mines employed fine, incombustible dusts for distribution throughout their mines as a means of preventing or checking coal-dust explosions. Limestone dust is particularly satisfactory for this purpose, because it is essentially calcium carbonate, which is not injurious to the lungs, and because, being white, the proportion of inert material present can be estimated readily. Limestone with a high silica content is undesirable. Screen-size specifications are not exacting. Those approved by the Bureau of Mines require that 100 percent shall pass through a 20-mesh screen, and 50 percent through a 200-mesh screen.

As the material commands a low price, it is usually furnished by quarries situated near coal mines. The use of limestone for this purpose has grown steadily under the impetus of a movement toward accident avoidance in coal mines. In 1936, 53,480 tons were so used. The quantity used passed the 100,000 ton mark in 1941 and exceeded 200,000 tons in 1945.

Magnesium Metal

One of the most striking events in the history of dolomite quarrying was the utilization of this rock during the second World War as an ore of magnesium metal. In 1943, at the height of this activity, 12 companies reported production of 887,830 tons of dolomite for this use. The producing states, in order of importance, were Ohio, Texas, Washington, California, Illinois, Wisconsin, Connecticut, and New York. In 1944, nine companies reported an output of 652,610 tons. In 1945, magnesium-metal production had been cut back so far as a result of the cessation of hostilities that only two companies, both in Ohio, reported output of dolomite for this use, and the total figure is, therefore, concealed.

Dolomitic lime was also used for magnesium-metal manufacture, but the quantity so used was included under sales for all metallurgical applications.

Insecticides, Fungicides, and Disinfectants

An important application of lime which consumes 60,000 to over 80,000 tons a year is the preparation of insecticides and related products. The more important of them, from the standpoint of their lime content, are calcium arsenate, lime-sulfur, and Bordeaux mixture. For calcium arsenate and Bordeaux mixture manufacture, either quicklime or hydrated lime may be used. The quicklime should contain not less than 92.5 percent available calcium oxide and the hydrated lime not less than 90 percent available calcium hydroxide. The lime should contain not more than 1.5 percent magnesium oxide. No specific requirements for lime in lime-sulfur mixture have been established, but the lime should contain very little inert material, and the magnesia content should be low because magnesium compounds readily decompose, producing hydrogen sulfide and liberating sulfur.

Leather

In 1945, 81,213 short tons of lime were sold to tanneries. The use of lime in tanneries is virtually confined to the dehairing (depilation) of the hides. Both quicklime and hydrated lime are used, and the available lime content should be at least 85 percent. High-calcium lime is generally used, but in making Morocco leather high-magnesium lime is employed.

Sewage and Trade-Waste Treatment

Much progress has been made in the treatment of both sewage and the waste water from chemical and industrial plants. Lime is used, in conjunction with iron and aluminum salts, for coagulation of solids. It is also used to control the reaction in sludge digestion, to assist in the dewatering process, and to neutralize industrial wastes. In 1939 less than 17,000 tons of lime were applied to these uses; by 1945 the quantity had grown to 71,496 tons. No definite specifications have been established for lime employed in sewage treatment, but a lime as pure as that used in water purification is required.

Poultry Grit

The use of limestone as poultry grit has increased greatly during the past 10 years—from less than 23,000 tons in 1936 to 114,670 tons in 1945. Almost any type of limestone may be so used. It is crushed into granules and screened to uniform sizes.

Petroleum Refining

Lime is used in some refineries to neutralize organic acids present in the petroleum and also to sweeten naphtha and gasoline during the refining process. Grit-free hydrated, high-calcium lime is used to form calcium soaps—important constituents of cup greases, pressure-gun, and cold-set greases. Lime is also used in making candles.

Miscellaneous Processing Industries

Limestone or lime derived from it are used in quantities ranging from a few hundred to several thousand tons a year in a great variety of products and processes. Most of them are given in the second column of table 2 and in the footnotes thereto.

Thus, the production of limestone and its calcination product, lime, is an important industry in spite of the commonplace occurrence of the raw material. The uses of both limestone and lime should expand as new processes are developed. Producers should give constant consideration to methods of treatment or selection that will improve their products for special uses insofar as this is feasible under market conditions. Limestone and lime are low-cost commodities that are likely to replace other materials wherever substitution is possible.

AN ACT FOR THE DEVELOPMENT AND CONTROL OF ATOMIC ENERGY

[PUBLIC LAW 585—79TH CONGRESS]

[CHAPTER 724—2D SESSION]

[S. 1717]

AN ACT

For the development and control of atomic energy.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

DECLARATION OF POLICY

SECTION 1. (a) FINDINGS AND DECLARATION.—Research and experimentation in the field of nuclear chain reaction have attained the stage at which the release of atomic energy on a large scale is practical. The significance of the atomic bomb for military purposes is evident. The effect of the use of atomic energy for civilian purposes upon the social, economic, and political structures of today cannot now be determined. It is a field in which unknown factors are involved. Therefore, any legislation will necessarily be subject to revision from time to time. It is reasonable to anticipate, however, that tapping this new source of energy will cause profound changes in our present way of life. Accordingly, it is hereby declared to be the policy of the people of the United States that, subject at all times to the paramount objective of assuring the common defense and security, the development and utilization of atomic energy shall, so far as practicable, be directed toward improving the public welfare, increasing the standard of living, strengthening free competition in private enterprise, and promoting world peace.

(b) PURPOSE OF ACT.—It is the purpose of this Act to effectuate the policies set out in section 1 (a) by providing, among others, for the following major programs relating to atomic energy:

(1) A program of assisting and fostering private research and development to encourage maximum scientific progress;

(2) A program for the control of scientific and technical information which will permit the dissemination of such information to encourage scientific progress, and for the sharing on a reciprocal basis of information concerning the practical industrial application of atomic energy as soon as effective and enforceable safeguards against its use for destructive purposes can be devised;

(3) A program of federally conducted research and development to assure the Government of adequate scientific and technical accomplishment;

(4) A program for Government control of the production, ownership, and use of fissionable material to assure the common defense and security and to insure the broadest possible exploitation of the fields; and

(5) A program of administration which will be consistent with the foregoing policies and with international arrangements made by the United States, and which will enable the Congress to be currently informed so as to take further legislative action as may hereafter be appropriate.

ORGANIZATION

SEC. 2. (a) ATOMIC ENERGY COMMISSION.—

(1) There is hereby established an Atomic Energy Commission (herein called the Commission), which shall be composed of five members. Three members shall constitute a quorum of the Commission. The President shall designate one member as Chairman of the Commission.

(2) Members of the Commission shall be appointed by the President, by and with the advice and consent of the Senate. In submitting any nomination to the Senate, the President shall set forth the experience and the qualifications of the nominee. The term of office of each member of the Commission taking office prior to the expiration of two years after the date of enactment of this Act shall expire upon the expiration of such two years. The term of office of each member of the Commission taking office after the expiration of two years from the date of enactment of this Act shall be five years, except that (A) the terms of office of the members first taking office after the expiration of two years from the date of enactment of this Act shall expire, as designated by the President at the time of appointment, one at the end of three years, one at the end of four years, one at the end of five years, one at the end of six years, and one at the end of seven years, after the date of enactment of this Act; and (B) any member appointed to fill a vacancy occurring prior to the expiration of the term for which his predecessor was appointed shall be appointed for the remainder of such term. Any member of the Commission may be removed by the President for inefficiency, neglect of duty, or malfeasance in office. Each member, except the Chairman, shall receive compensation at the rate of $15,000 per annum; and the Chairman shall receive compensation at the rate of $17,500 per annum. No member of the Commission shall engage in any other business, vocation, or employment than that of serving as a member of the Commission.

(3) The principal office of the Commission shall be in the District of Columbia, but the Commission or any duly authorized representative may exercise any or all of its powers in any place. The Commission shall hold such meetings, conduct such hearings, and receive such reports as may be necessary to enable it to carry out the provisions of this Act.

(4) There are hereby established within the Commission—

> (A) a General Manager, who shall discharge such of the administrative and executive functions of the Commission as the Commission may direct. The General Manager shall be appointed by the President by and with the advice and consent of the Senate, and shall receive compensation at the rate of $15,000 per annum. The Commission may make recommendations to the President with respect to the appointment or removal of the General Manager.
>
> (B) a Division of Research, a Division of Production, a Division of Engineering, and a Division of Military Application. Each division shall be under the direction of a Director who shall be appointed by the Commission, and shall receive compensation at the rate of $14,000 per annum. The Director of the Division of Military Application shall be a member of the armed forces. The Commission shall require each such division to exercise such of the Commission's powers under this Act as the Com-

mission may determine, except that the authority granted under section 3 (a) of this Act shall not be exercised by the Division of Research.

(b) GENERAL ADVISORY COMMITTEE.—There shall be a General Advisory Committee to advise the Commission on scientific and technical matters relating to materials, production, and research and development, to be composed of nine members, who shall be appointed from civilian life by the President. Each member shall hold office for a term of six years, except that (1) any member appointed to fill a vacancy occurring prior to the expiration of the term for which his predecessor was appointed, shall be appointed for the remainder of such term; and (2) the terms of office of the members first taking office after the date of the enactment of this Act shall expire, as designated by the President at the time of appointment, three at the end of two years, three at the end of four years, and three at the end of six years, after the date of the enactment of this Act. The Committee shall designate one of its own members as Chairman. The Committee shall meet at least four times in every calendar year. The members of the Committee shall receive a per diem compensation of $50 for each day spent in meetings or conferences, and all members shall receive their necessary traveling or other expenses while engaged in the work of the Committee.

(c) MILITARY LIAISON COMMITTEE.—There shall be a Military Liaison Committee consisting of representatives of the Departments of War and Navy, detailed or assigned thereto, without additional compensation, by the Secretaries of War and Navy in such number as they may determine. The Commission shall advise and consult with the Committee on all atomic energy matters which the Committee deems to relate to military applications, including the development, manufacture, use, and storage of bombs, the allocation of fissionable material for military research, and the control of information relating to the manufacture or utilization of atomic weapons. The Commission shall keep the Committee fully informed of all such matters before it and the Committee shall keep the Commission fully informed of all atomic energy activities of the War and Navy Departments. The Committee shall have authority to make written recommendations to the Commission on matters relating to military applications from time to time as it may deem appropriate. If the Committee at any time concludes that any action, proposed action, or failure to act of the Commission on such matters is adverse to the responsibilities of the Departments of War or Navy, derived from the Constitution, laws, and treaties, the Committee may refer such action, proposed action, or failure to act to the Secretaries of War and Navy. If either Secretary concurs, he may refer the matter to the President, whose decision shall be final.

(d) APPOINTMENT OF ARMY AND NAVY OFFICERS.—Notwithstanding the provisions of section 1222 of the Revised Statutes (U. S. C., 1940 edition, title 10, sec. 576), section 212 of the Act entitled ''An Act making appropriations for the Legislative Branch of the Government for the fiscal year ending June 30, 1933, and for other purposes'', approved June 30, 1932, as amended (U. S. C., 1940 edition, title 5, sec. 59a), section 2 of the Act entitled ''An Act making appropriations for the legislative, executive, and judicial expenses of the Government for the fiscal year ending June thirtieth, eighteen hundred and ninety-five, and for other purposes'', approved July 31, 1894, as amended (U. S. C., 1940 edition, title 5, sec. 62), or any other law, any active or retired officer of the Army or the Navy may serve as Director of the Division of Military Application established by subsection (a) (4) (B) of this section, without prejudice to his commissioned status as such officer. Any such officer serving as Director of the Division of Military Application shall receive, in addition to his pay from the United States as such officer, an amount equal to the difference between such pay and the compensation prescribed in subsection (a) (4) (B) of this section.

RESEARCH

SEC. 3. (a) RESEARCH ASSISTANCE.—The Commission is directed to exercise its powers in such manner as to insure the continued conduct of research and development activities in the fields specified below by private or public institutions or persons and to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields. To this end the Commission is authorized and directed to make arrangements (including contracts, agreements, and loans) for the conduct of research and development activities relating to—

(1) nuclear processes;

(2) the theory and production of atomic energy, including processes, materials, and devices related to such production;

(3) utilization of fissionable and radioactive materials for medical, biological, health, or military purposes;

(4) utilization of fissionable and radioactive materials and processes entailed in the production of such materials for all other purposes, including industrial uses; and

(5) the protection of health during research and production activities.

The Commission may make such arrangements without regard to the provisions of section 3709 of the Revised Statutes (U. S. C., title 41, sec. 5) upon certification by the Commission that such action is necessary in the interest of the common defense and security, or upon a showing that advertising is not reasonably practicable, and may make partial and advance payments under such arrangements, and may make available for use in connection therewith such of its equipment and facilities as it may deem desirable. Such arrangements shall contain such provisions to protect health, to minimize danger from explosion and other hazards to life or property, and to require the reporting and to permit the inspection of work performed thereunder, as the Commission may determine; but shall not contain any provisions or conditions which prevent the dissemination of scientific or technical information, except to the extent such dissemination is prohibited by law.

(b) RESEARCH BY THE COMMISSION.—The Commission is authorized and directed to conduct, through its own facilities, activities and studies of the types specified in subsection (a) above.

PRODUCTION OF FISSIONABLE MATERIAL

SEC. 4. (a) DEFINITION.—As used in this Act, the term ''produce'', when used in relation to fissionable material, means to manufacture, produce, or refine fissionable material, as distinguished from source materials as defined in section 5 (b) (1), or to separate fissionable material from other substances in which such material may be contained or to produce new fissionable material.

(b) PROHIBITION.—It shall be unlawful for any person to own any facilities for the production of fissionable material or for any person to produce fissionable material, except to the extent authorized by subsection (c).

(c) OWNERSHIP AND OPERATION OF PRODUCTION FACILITIES.—

(1) OWNERSHIP OF PRODUCTION FACILITIES.—The Commission, as agent of and on behalf of the United States, shall be the exclusive owner of all facilities for the production of fissionable material other than facilities which (A) are useful in the conduct of research and development activities in the fields specified in section 3, and (B) do not, in the opinion of the Commission, have a potential production rate adequate to enable the operator of such facilities to produce within a reasonable period of time a sufficient quantity of fissionable material to produce an atomic bomb or any other atomic weapon.

(2) OPERATION OF THE COMMISSION'S PRODUCTION FACILITIES.—The Commission is authorized and directed to produce or to provide for the production of fissionable material in its own facilities. To the extent deemed necessary, the Commission is authorized to make, or to continue in effect, contracts with persons obligating them to produce fissionable material in facilities owned by the Commission. The Commission is also authorized to enter into research and development contracts authorizing the contractor to produce fissionable material in facilities owned by the Commission to the extent that the production of such fissionable material may be incident to the conduct of research and development activities under such contracts. Any contract entered into under this section shall contain provisions (A) prohibiting the contractor with the Commission from subcontracting any part of the work he is obligated to perform under the contract, except as authorized by the Commission, and (B) obligating the contractor to make such reports to the Commission as it may deem appropriate with respect to his activities under the contract, to submit to frequent inspection by employees of the Commission of all such activities, and to comply with all safety and security regulations which may be prescribed by the Commission. Any contract made under the provisions of this paragraph may be made without regard to the provisions of section 3709 of the Revised Statutes (U. S. C., title 41, sec. 5) upon certification by the Commission that such action is necessary in the interest of the common defense and security, or upon a showing that advertising is not reasonably practicable, and partial and advance payments may be made under such contracts. The President shall determine at least once each year the quantities of fissionable material to be produced under this paragraph.

(3) OPERATION OF OTHER PRODUCTION FACILITIES.—Fissionable material may be produced in the conduct of research and development activities in facilities which, under paragraph (1) above, are not required to be owned by the Commission.

(d) IRRADIATION OF MATERIALS.—For the purpose of increasing the supply of radioactive materials, the Commission and persons lawfully producing or utilizing fissionable material are authorized to expose materials of any kind to the radiation incident to the processes of producing or utilizing fissionable material.

(e) MANUFACTURE OF PRODUCTION FACILITIES.—Unless authorized by a license issued by the Commission, no person may manufacture, produce, transfer, or acquire any facilities for the production of fissionable material. Licenses shall be issued in accordance with such procedures as the Commission may by regulation establish and shall be issued in accordance with such standards and upon such conditions as will restrict the production and distribution of such facilities to effectuate the policies and purposes of this Act. Nothing in this section shall be deemed to require a license for such manufacture, production, transfer, or acquisition incident to or for the conduct of research or development activities in the United States of the types specified in section 3, or to prohibit the Commission from manufacturing or producing such facilities for its own use.

CONTROL OF MATERIALS

SEC. 5. (a) FISSIONABLE MATERIALS.—

(1) DEFINITION.—As used in this Act, the term ''fissionable material'' means plutonium, uranium enriched in the isotope 235, any other material which the Commission determines to be capable of releasing substantial quantities of energy through nuclear chain reaction of the material, or any material artificially enriched by any of the foregoing; but does not include source materials, as defined in section 5 (b) (1).

(2) GOVERNMENT OWNERSHIP OF ALL FISSIONABLE MATERIAL.—All right, title, and interest within or under the jurisdiction of the United States, in or to any fissionable material, now or hereafter produced, shall be the property of the Commission, and shall be deemed to be vested in the Commission by virtue of this Act. Any person owning any interest in any fissionable material at the time of the enactment of this Act, or owning any interest in any material at the time when such material is hereafter determined to be a fissionable material, or who lawfully produces any fissionable material incident to privately financed research or development activities, shall be paid just compensation therefor. The Commission may, by action consistent with the provisions of paragraph (4) below, authorize any such person to retain possession of such fissionable material, but no person shall have any title in or to any fissionable material.

(3) PROHIBITION.—It shall be unlawful for any person, after sixty days from the effective date of this Act to (A) possess or transfer any fissionable material, except as authorized by the Commission, or (B) export from or import into the United States any fissionable material, or (C) directly or indirectly engage in the production of any fissionable material outside of the United States.

(4) DISTRIBUTION OF FISSIONABLE MATERIAL.—Without prejudice to its continued ownership thereof, the Commission is authorized to distribute fissionable material owned by it, with or without charge, to applicants requesting such material (A) for the conduct of research or development activities either independently or under contract or other arrangement with the Commission, (B) for use in medical therapy, or (C) for use pursuant to a license issued under the authority of section 7.

Such material shall be distributed in such quantities and on such terms that no applicant will be enabled to obtain an amount sufficient to construct a bomb or other military weapon. The Commission is directed to distribute sufficient fissionable material to permit the conduct of widespread independent research and development activity, to the maximum extent practicable. In determining the quantities of fissionable material to be distributed, the Commission shall make such provisions for its own needs and for the conservation of fissionable material as it may determine to be necessary in the national interest for the future development of atomic energy. The Commission shall not distribute any material to any applicant, and shall recall any distributed material from any applicant, who is not equipped to observe or who fails to observe such safety standards to protect health and to minimize danger from explosion or other hazard to life or property as may be established by the Commission, or who uses such material in violation of law or regulation of the Commission or in a manner other than as disclosed in the application therefor.

(5) The Commission is authorized to purchase or otherwise acquire any fissionable material or any interest therein outside the United States, or any interest in facilities for the production of fissionable material, or in real property on which such facilities are located, without regard to the provisions of section 3709 of the Revised Statutes (U. S. C., title 41, sec. 5) upon certification by the Commission that such action is necessary in the interest of the common defense and security, or upon a showing that advertising is not reasonably practicable, and partial and advance payments may be made under contracts for such purposes. The Commission is further authorized to take, requisition, or condemn, or otherwise acquire any interest in such facilities or real property, and just compensation shall be made therefor.

(b) SOURCE MATERIALS.—

(1) DEFINITION.—As used in this Act, the term ''source material'' means uranium, thorium, or any other material which is determined by the Commission, with the approval of the President, to be peculiarly essential to the production of fissionable materials; but includes ores only if they contain one or more of the foregoing materials in such concentration as the Commission may by regulation determine from time to time.

(2) LICENSE FOR TRANSFERS REQUIRED.—Unless authorized by a license issued by the Commission, no person may transfer or deliver, receive possession of or title to, or export from the United States any source material after removal from its place of deposit in nature, except that licenses shall not be required for quantities of source materials which, in the opinion of the Commission, are unimportant.

(3) ISSUANCE OF LICENSES.—The Commission shall establish such standards for the issuance, refusal, or revocation of licenses as it may deem necessary to assure adequate source materials for production, research, or development activities pursuant to this Act or to prevent the use of such materials in a manner inconsistent with the national welfare. Licenses shall be issued in accordance with such procedures as the Commission may by regulation establish.

(4) REPORTING.—The Commission is authorized to issue such regulations or orders requiring reports of ownership, possession, extraction, refining, shipment, or other handling of source materials as it may deem

necessary, except that such reports shall not be required with respect to (A) any source material prior to removal from its place of deposit in nature, or (B) quantities of source materials which in the opinion of the Commission are unimportant or the reporting of which will discourage independent prospecting for new deposits.

(5) ACQUISITION.—The Commission is authorized and directed to purchase, take, requisition, condemn, or otherwise acquire, supplies of source materials or any interest in real property containing deposits of source materials to the extent it deems necessary to effectuate the provisions of this Act. Any purchase made under this paragraph may be made without regard to the provisions of section 3709 of the Revised Statutes (U. S. C., title 41, sec. 5) upon certification by the Commission that such action is necessary in the interest of the common defense and security, or upon a showing that advertising is not reasonably practicable, and partial and advance payments may be made thereunder. The Commission may establish guaranteed prices for all source materials delivered to it within a specified time. Just compensation shall be made for any property taken, requisitioned, or condemned under this paragraph.

(6) EXPLORATION.—The Commission is authorized to conduct and enter into contracts for the conduct of exploratory operations, investigations, and inspections to determine the location, extent, mode of occurrence, use, or conditions of deposits or supplies of source materials, making just compensation for any damage or injury occasioned thereby. Such exploratory operations may be conducted only with the consent of the owner, but such investigations and inspections may be conducted with or without such consent.

(7) PUBLIC LANDS.—All uranium, thorium, and all other materials determined pursuant to paragraph (1) of this subsection to be peculiarly essential to the production of fissionable material, contained, in whatever concentration, in deposits in the public lands are hereby reserved for the use of the United States subject to valid claims, rights, or privileges existing on the date of the enactment of this Act: *Provided, however,* That no individual, corporation, partnership, or association, which had any part, directly or indirectly, in the development of the atomic bomb project, may benefit by any location, entry, or settlement upon the public domain made after such individual, corporation, partnership, or association took part in such project, if such individual, corporation, partnership, or association, by reason of having had such part in the development of the atomic bomb project, acquired confidential official information as to the existence of deposits of such uranium, thorium, or other materials in the specific lands upon which such location, entry, or settlement is made, and subsequent to the date of the enactment of this Act made such location, entry, or settlement or caused the same to be made for his, its, or their benefit. The Secretary of the Interior shall cause to be inserted in every patent, conveyance, lease, permit, or other authorization hereafter granted to use the public lands or their mineral resources, under any of which there might result the extraction of any materials so reserved, a reservation to the United States of all such materials, whether or not of commercial value, together with the right of the United States through its authorized agents or representatives at any time to enter upon the land and prospect for, mine, and remove the same,

making just compensation for any damage or injury occasioned thereby. Any lands so patented, conveyed, leased, or otherwise disposed of may be used, and any rights under any such permit or authorization may be exercised, as if no reservation of such materials had been made under this subsection; except that, when such use results in the extraction of any such material from the land in quantities which may not be transferred or delivered without a license under this subsection, such material shall be the property of the Commission and the Commission may require delivery of such material to it by any possesor thereof after such material has been separated as such from the ores in which it was contained. If the Commission requires the delivery of such material to it, it shall pay to the person mining or extracting the same, or to such other person as the Commission determines to be entitled thereto, such sums, including profits, as the Commission deems fair and reasonable for the discovery, mining, development, production, extraction, and other services performed with respect to such material prior to such delivery, but such payment shall not include any amount on account of the value of such material before removal from its place of deposit in nature. If the Commission does not require delivery of such material to it, the reservation made pursuant to this paragraph shall be of no further force or effect.

(c) BYPRODUCT MATERIALS.—

(1) DEFINITION.—As used in this Act, the term "byproduct material" means any radioactive material (except fissionable material) yielded in or made radioactive by exposure to the radiation incident to the processes of producing or utilizing fissionable material.

(2) DISTRIBUTION.—The Commission is authorized to distribute, with or without charge, byproduct materials to applicants seeking such materials for research or development activity, medical therapy, industrial uses, or such other useful applications as may be developed. In distributing such materials, the Commission shall give preference to applicants proposing to use such materials in the conduct of research and development activity or medical therapy. The Commission shall not distribute any byproduct materials to any applicant, and shall recall any distributed materials from any applicant, who is not equipped to observe or who fails to observe such safety standards to protect health as may be established by the Commission or who uses such materials in violation of law or regulation of the Commission or in a manner other than as disclosed in the application therefor.

(d) GENERAL PROVISIONS.—The Commission shall not—

(1) distribute any fissionable material to (A) any person for a use which is not under or within the jurisdiction of the United States, (B) any foreign government, or (C) any person within the United States if, in the opinion of the Commission, the distribution of such fissionable material to such person would be inimical to the common defense and security.

(2) license any person to transfer or deliver, receive possession of or title to, or export from the United States any source material if, in the opinion of the Commission, the issuance of a license to such person for such purpose would be inimical to the common defense and security.

MILITARY APPLICATIONS OF ATOMIC ENERGY

SEC. 6 (a) AUTHORITY.—The Commission is authorized to—

(1) conduct experiments and do research and development work in the military application of atomic energy; and

(2) engage in the production of atomic bombs, atomic bomb parts, or other military weapons utilizing fissionable materials; except that such activities shall be carried on only to the extent that the express consent and direction of the President of the United States has been obtained, which consent and direction shall be obtained at least once each year.

The President from time to time may direct the Commission (1) to deliver such quantities of fissionable materials or weapons to the armed forces for such use as he deems necessary in the interest of national defense or (2) to authorize the armed forces to manufacture, produce, or acquire any equipment or device utilizing fissionable material or atomic energy as a military weapon.

(b) PROHIBITION.—It shall be unlawful for any person to manufacture, produce, transfer, or acquire any equipment or device utilizing fissionable material or atomic energy as a military weapon, except as may be authorized by the Commission. Nothing in this subsection shall be deemed to modify the provisions of section 4 of this Act, or to prohibit research activities in respect of military weapons, or to permit the export of any such equipment or device.

UTILIZATION OF ATOMIC ENERGY

SEC. 7. (a) LICENSE REQUIRED.—It shall be unlawful, except as provided in sections 5 (a) (4) (A) or (B) or 6 (a), for any person to manufacture, produce, or export any equipment or device utilizing fissionable material or atomic energy or to utilize fissionable material or atomic energy with or without such equipment or device, except under and in accordance with a license issued by the Commission authorizing such manufacture, production, export, or utilization. No license may permit any such activity if fissionable material is produced incident to such activity, except as provided in sections 3 and 4. Nothing in this section shall be deemed to require a license for the conduct of research or development activities relating to the manufacture of such equipment or devices or the utilization of fissionable material or atomic energy, or for the manufacture or use of equipment or devices for medical therapy.

(b) REPORT TO CONGRESS.—Whenever in its opinion any industrial, commercial, or other nonmilitary use of fissionable material or atomic energy has been sufficiently developed to be of practical value, the Commission shall prepare a report to the President stating all the facts with respect to such use, the Commission's estimate of the social, political, economic, and international effects of such use and the Commission's recommendations for necessary or desirable supplemental legislation. The President shall then transmit this report to the Congress together with his recommendations. No license for any manufacture, production, export, or use shall be issued by the Commission under this section until after (1) a report with respect to such manufacture, production, export, or use has been filed with the Congress; and

(2) a period of ninety days in which the Congress was in session has elapsed after the report has been so filed. In computing such period of ninety days, there shall be excluded the days on which either House is not in session because of an adjournment of more than three days.

(c) ISSUANCE OF LICENSES.—After such ninety-day period, unless hereafter prohibited by law, the Commission may license such manufacture, production, export, or use in accordance with such procedures and subject to such conditions as it may by regulation establish to effectuate the provisions of this Act. The Commission is authorized and directed to issue licenses on a nonexclusive basis and to supply to the extent available appropriate quantities of fissionable material to licensees (1) whose proposed activities will serve some useful purpose proportionate to the quantities of fissionable material to be consumed; (2) who are equipped to observe such safety standards to protect health and to minimize danger from explosion or other hazard to life or property as the Commission may establish; and (3) who agree to make available to the Commission such technical information and data concerning their activities pursuant to such licenses as the Commission may determine necessary to encourage similar activities by as many licensees as possible. Each such license shall be issued for a specified period, shall be revocable at any time by the Commission in accordance with such procedures as the Commission may establish, and may be renewed upon the expiration of such period. Where activities under any license might serve to maintain or to foster the growth of monoply, restraint of trade, unlawful competition, or other trade position inimical to the entry of new, freely competitive enterprises in the field, the Commission is authorized and directed to refuse to issue such license or to establish such conditions to prevent these results as the Commission, in consultation with the Attorney General, may determine. The Commission shall report promptly to the Attorney General any information it may have with respect to any utilization of fissionable material or atomic energy which appears to have these results. No license may be given to any person for activities which are not under or within the jurisdiction of the United States, to any foreign government, or to any person within the United States if, in the opinion of the Commission, the issuance of a license to such person would be inimical to the common defense and security.

(d) BYPRODUCT POWER.—If energy which may be utilized is produced in the production of fissionable material, such energy may be used by the Commission, transferred to other Government agencies, or sold to public or private utilities under contracts providing for reasonable resale prices.

INTERNATIONAL ARRANGEMENTS

SEC. 8. (a) DEFINITION.—As used in this Act, the term "international arrangement" shall mean any treaty approved by the Senate or international agreement hereafter approved by the Congress, during the time such treaty or agreement is in full force and effect.

(b) EFFECT OF INTERNATIONAL ARRANGEMENTS.—Any provision of this Act or any action of the Commission to the extent that it conflicts with the provisions of any international arrangement made after the date of enactment of this Act shall be deemed to be of no further force or effect.

(c) Policies Contained in International Arrangements.—In the performance of its functions under this Act, the Commission shall give maximum effect to the policies contained in any such international arrangement.

PROPERTY OF THE COMMISSION

Sec. 9. (a) The President shall direct the transfer to the Commission of all interests owned by the United States or any Government agency in the following property:

(1) All fissionable material; all atomic weapons and parts thereof; all facilities, equipment, and materials for the processing, production, or utilization of fissionable material or atomic energy; all processes and technical information of any kind, and the source thereof (including data, drawings, specifications, patents, patent applications, and other sources relating to the processing, production, or utilization of fissionable material or atomic energy); and all contracts, agreements, leases, patents, applications for patents, inventions and discoveries (whether patented or unpatented), and other rights of any kind concerning any such items;

(2) All facilities, equipment, and materials, devoted primarily to atomic energy research and development; and

(3) Such other property owned by or in the custody or control of the Manhattan Engineer District or other Government agencies as the President may determine.

(b) In order to render financial assistance to those States and localities in which the activities of the Commission are carried on and in which the Commission has acquired property previously subject to State and local taxation, the Commission is authorized to make payments to State and local governments in lieu of property taxes. Such payments may be in the amounts, at the times, and upon the terms the Commission deems appropriate, but the Commission shall be guided by the policy of not making payments in excess of the taxes which would have been payable for such property in the condition in which it was acquired, except in cases where special burdens have been cast upon the State or local government by activities of the Commission, the Manhattan Engineer District or their agents. In any such case, any benefit accruing to the State or local government by reason of such activities shall be considered in determining the amount of the payment. The Commission, and the property, activities, and income of the Commission, are hereby expressly exempted from taxation in any manner or form by any State, county, municipality, or any subdivision thereof.

CONTROL OF INFORMATION

Sec. 10. (a) Policy.—It shall be the policy of the Commission to control the dissemination of restricted data in such a manner as to assure the common defense and security. Consistent with such policy, the Commission shall be guided by the following principles:

(1) That until Congress declares by joint resolution that effective and enforceable international safeguards against the use of atomic energy for destructive purposes have been established, there shall be no exchange of information with other nations with respect to the use of atomic energy for industrial purposes; and

(2) That the dissemination of scientific and technical information relating to atomic energy should be permitted and encouraged so as to provide that free interchange of ideas and criticisms which is essential to scientific progress.

(b) RESTRICTIONS.—

(1) The term "restricted data" as used in this section means all data concerning the manufacture or utilization of atomic weapons, the production of fissionable material, or the use of fissionable material in the production of power, but shall not include any data which the Commission from time to time determines may be published without adversely affecting the common defense and security.

(2) Whoever, lawfully or unlawfully, having possession of, access to, control over, or being entrusted with, any document, writing, sketch, photograph, plan, model, instrument, appliance, note or information involving or incorporating restricted data—

(A) communicates, transmits, or discloses the same to any individual or person, or attempts or conspires to do any of the foregoing, with intent to injure the United States or with intent to secure an advantage to any foreign nation, upon conviction thereof, shall be punished by death or imprisonment for life (but the penalty of death or imprisonment for life may be imposed only upon recommendation of the jury and only in cases where the offense was committed with intent to injure the United States); or by a fine of not more than $20,000 or imprisonment for not more than twenty years, or both;

(B) communicates, transmits, or discloses the same to any individual or person, or attempts or conspires to do any of the foregoing, with reason to believe such data will be utilized to injure the United States or to secure an advantage to any foreign nation, shall, upon conviction, be punished by a fine of not more than $10,000 or imprisonment for not more than ten years, or both.

(3) Whoever, with intent to injure the United States or with intent to secure an advantage to any foreign nation, acquires or attempts or conspires to acquire any document, writing, sketch, photograph, plan, model, instrument, appliance, note or information involving or incorporating restricted data shall, upon conviction thereof, be punished by death or imprisonment for life (but the penalty of death or imprisonment for life may be imposed only upon recommendation of the jury and only in cases where the offense was committed with intent to injure the United States); or by a fine of not more than $20,000 or imprisonment for not more than twenty years, or both.

(4) Whoever, with intent to injure the United States or with intent to secure an advantage to any foreign nation, removes, conceals, tampers with, alters, mutilates, or destroys any document, writing, sketch, photograph, plan, model, instrument, appliance, or note involving or incorporating restricted data and used by any individual or person in connection with the production of fissionable material, or research or development relating to atomic energy, conducted by the United States, or financed in whole or in part by Federal funds, or conducted with the aid of fissionable material, shall be punished by death or imprisonment for life (but the penalty of death or imprisonment for life may be imposed

only upon recommendation of the jury and only in cases where the offense was committed with intent to injure the United States); or by a fine of not more than $20,000 or imprisonment for not more than twenty years or both.

(5) (A) No person shall be prosecuted for any violation under this section unless and until the Attorney General of the United States has advised the Commission with respect to such prosecution and no such prosecution shall be commenced except upon the express direction of the Attorney General of the United States.

(B) (i) No arrangement shall be made under section 3, no contract shall be made or continued in effect under section 4, and no license shall be issued under section 4 (e) or 7, unless the person with whom such arrangement is made, the contractor or prospective contractor, or the prospective licensee agrees in writing not to permit any individual to have access to restricted data until the Federal Bureau of Investigation shall have made an investigation and report to the Commission on the character, associations, and loyalty of such individual and the Commission shall have determined that permitting such person to have access to restricted data will not endanger the common defense or security.

(ii) Except as authorized by the Commission in case of emergency, no individual shall be employed by the Commission until the Federal Bureau of Investigation shall have made an investigation and report to the Commission on the character, associations, and loyalty of such individual.

(iii) Notwithstanding the provisions of subparagraphs (i) and (ii), during such period of time after the enactment of this Act as may be necessary to make the investigation, report, and determination required by such paragraphs, (a) any individual who was permitted access to restricted data by the Manhattan Engineer District may be permitted access to restricted data and (b) the Commission may employ any individual who was employed by the Manhattan Engineer District.

(iv) To protect against the unlawful dissemination of restricted data and to safeguard facilities, equipment, materials, and other property of the Commission, the President shall have authority to utilize the services of any Government agency to the extent he may deem necessary or desirable.

(C) All violations of this Act shall be investigated by the Federal Bureau of Investigation of the Department of Justice.

(6) This section shall not exclude the applicable provisions of any other laws, except that no Government agency shall take any action under such other laws inconsistent with the provisions of this section.

(c) INSPECTIONS, RECORDS, AND REPORTS.—The Commission is—

(1) authorized by regulation or order to require such reports and the keeping of such records with respect to, and to provide for such inspections of, activities and studies of types specified in section 3 and of activities under licenses issued pursuant to section 7 as may be necessary to effectuate the purposes of this Act;

(2) authorized and directed by regulation or order to require regular reports and records with respect to, and to pro-

vide for frequent inspections of, the production of fissionable material in the conduct of research and development activities.

PATENTS AND INVENTIONS

SEC. 11. (a) PRODUCTION AND MILITARY UTILIZATION.

(1) No patent shall hereafter be granted for any invention or discovery which is useful solely in the production of fissionable material or in the utilization of fissionable material or atomic energy for a military weapon. Any patent granted for any such invention or discovery is hereby revoked, and just compensation shall be made therefor.

(2) No patent hereafter granted shall confer any rights with respect to any invention or discovery to the extent that such invention or discovery is used in the production of fissionable material or in the utilization of fissionable material or atomic energy for a military weapon. Any rights conferred by any patent heretofore granted for any invention or discovery are hereby revoked to the extent that such invention or discovery is so used, and just compensation shall be made therefor.

(3) Any person who has made or hereafter makes any invention or discovery useful in the production of fissionable material or in the utilization of fissionable material or atomic energy for a military weapon shall file with the Commission a report containing a complete description thereof, unless such invention or discovery is described in an application for a patent filed in the Patent Office by such person within the time required for the filing of such report. The report covering any such invention or discovery shall be filed on or before whichever of the following is the latest: (A) The sixtieth day after the date of enactment of this Act; (B) the sixtieth day after the completion of such invention or discovery; or (C) the sixtieth day after such person first discovers or first has reason to believe that such invention or discovery is useful in such production or utilization.

(b) USE OF INVENTIONS FOR RESEARCH.—No patent hereafter granted shall confer any rights with respect to any invention or discovery to the extent that such invention or discovery is used in the conduct of research or development activities in the fields specified in section 3. Any rights conferred by any patent heretofore granted for any invention or discovery are hereby revoked to the exent that such invention or discovery is so used, and just compensation shall be made therefor.

(c) NONMILITARY UTILIZATION.—

(1) It shall be the duty of the Commission to declare any patent to be affected with the public interest if (A) the invention or discovery covered by the patent utilizes or is essential in the utilization of fissionable material or atomic energy; and (B) the licensing of such invention or discovery under this subsection is necessary to effectuate the policies and purposes of this Act.

(2) Whenever any patent has been declared, pursuant to paragraph (1), to be affected with the public interest—

(A) The Commission is hereby licensed to use the invention or discovery covered by such patent in performing any of its powers under this Act; and

(B) Any person to whom a license has been issued under section 7 is hereby licensed to use the invention or discovery

> covered by such patent to the extent that such invention or discovery is used by him in carrying on the activities authorized by his license under section 7.

The owner of the patent shall be entitled to a reasonable royalty fee for any use of an invention or discovery licensed by this subsection. Such royalty fee may be agreed upon by such owner and the licensee, or in the absence of such agreement shall be determined by the Commission.

(3) No court shall have jurisdiction or power to stay, restrain, or otherwise enjoin the use of any invention or discovery by a licensee, to the extent that such use is licensed by paragraph (2) above, on the ground of infringement of any patent. If in any action for infringement against such licensee the court shall determine that the defendant is exercising such license, the measure of damages shall be the royalty fee determined pursuant to this section, together with such costs, interest, and reasonable attorney's fees as may be fixed by the court. If no royalty fee has been determined, the court shall stay the proceeding until the royalty fee is determined pursuant to this section. If any such licensee shall fail to pay such royalty fee, the patentee may bring an action in any court of competent jurisdiction for such royalty fee, together with such costs, interest, and reasonable attorney's fees as may be fixed by the court.

(d) ACQUISITION OF PATENTS.—The Commission is authorized to purchase, or to take, requisition, or condemn, and make just compensation for, (1) any invention or discovery which is useful in the production of fissionable material or in the utilization of fissionable material or atomic energy for a military weapon, or which utilizes or is essential in the utilization of fissionable material or atomic energy, or (2) any patent or patent application covering any such invention or discovery. The Commissioner of Patents shall notify the Commission of all applications for patents heretofore or hereafter filed which in his opinion disclose such inventions or discoveriees and shall provide the Commission access to all such applications.

(e) COMPENSATION AWARDS, AND ROYALTIES.—

(1) PATENT COMPENSATION BOARD.—The Commission shall designate a Patent Compensation Board, consisting of two or more employees of the Commission, to consider applications under this subsection.

(2) ELIGIBILITY.—

> (A) Any owner of a patent licensed under subsection (c) (2) or any licensee thereunder may make application to the Commission for the determination of a reasonable royalty fee in accordance with such procedures as it by regulation may establish.
>
> (B) Any person seeking to obtain the just compensation provided in subsections (a), (b), or (d) shall make application therefor to the Commission in accordance with such procedures as it may by regulation establish.
>
> (C) Any person making any invention or discovery useful in the production of fissionable material or in the utilization of fissionable material or atomic energy for a military weapon who is not entitled to compensation therefor under subsection (a) and who has complied with subsection (a) (3) above may make

application to the Commission for, and the Commission may grant, an award.

(D) Any person making application under this subsection shall have the right to be represented by counsel.

(3) STANDARDS.—

(A) In determining such reasonable royalty fee, the Commission shall take into consideration any defense, general or special, that might be pleaded by a defendant in an action for infringement, the extent to which, if any, such patent was developed through federally financed research, the degree of utility, novelty, and importance of the invention or discovery, and may consider the cost to the owner of the patent of developing such invention or discovery or acquiring such patent.

(B) In determining what constitutes just compensation under subsection (a), (b), or (d) above, the Commission shall take into account the considerations set forth in paragraph (A) above, and the actual use of such invention or discovery, and may determine that such compensation be paid in periodic payments or in a lump sum.

(C) In determining the amount of any award under paragraph (2) (C) of this subsection, the Commission shall take into account the considerations set forth in paragraph (A) above, and the actual use of such invention or discovery. Awards so made may be paid by the Commission in periodic payments or in a lump sum.

(4) JUDICIAL REVIEW.—Any person aggrieved by any determination of the Commission of an award or of a reasonable royalty fee may obtain a review of such determination in the Court of Appeals for the District of Columbia by filing in such court, within thirty days after notice of such determination, a written petition praying that such determination be set aside. A copy of such petition shall be forthwith served upon the Commission and thereupon the Commission shall file with the court a certified transcript of the entire record in the proceeding, including the findings and conclusions upon which the determination was based. Upon the filing of such transcript the court shall have exclusive jurisdiction upon the record certified to it to affirm the determination in its entirety or set it aside and remand it to the Commission for further proceedings. The findings of the Commission as to the facts, if supported by substantial evidence, shall be conclusive. The court's judgment shall be final, subject, however, to review by the Supreme Court of the United States upon writ of certiorari on petition therefor under section 240 of the Judicial Code (U. S. C., title 28, sec. 347), by the Commission or any party to the court proceeding.

GENERAL AUTHORITY

SEC. 12. (a) In the performance of its functions the Commission is authorized to—

(1) establish advisory boards to advise with and make recommendations to the Commission on legislation, policies, administration, research, and other matters;

(2) establish by regulation or order such standards and instructions to govern the possession and use of fissionable and byproduct materials as the Commission may deem necessary or desirable to protect health or to minimize danger from explosions and other hazards to life or property;

(3) make such studies and investigations, obtain such information, and hold such hearings as the Commission may deem necessary or proper to assist it in exercising any authority provided in this Act, or in the administration or enforcement of this Act, or any regulations or orders issued thereunder. For such purposes the Commission is authorized to administer oaths and affirmations, and by subpena to require any person to appear and testify, or to appear and produce documents, or both, at any designated place. No person shall be excused from complying with any requirements under this paragraph because of his privilege against self-incrimination, but the immunity provisions of the Compulsory Testimony Act of February 11, 1893 (U. S. C., title 49, sec. 46), shall apply with respect to any individual who specifically claims such privilege. Witnesses subpenaed under this subsection shall be paid the same fees and mileage as are paid witnesses in the district courts of the United States;

(4) appoint and fix the compensation of such officers and employees as may be necessary to carry out the functions of the Commission. Such officers and employees shall be appointed in accordance with the civil-service laws and their compensation fixed in accordance with the Classification Act of 1923, as amended, except that to the extent the Commission deems such action necessary to the discharge of its responsibilities, personnel may be employed and their compensation fixed without regard to such laws. The Commission shall make adequate provision for administrative review of any determination to dismiss any employee;

(5) acquire such materials, property, equipment, and facilities, establish or construct such buildings and facilities, and modify such buildings and facilities from time to time as it may deem necessary, and construct, acquire, provide, or arrange for such facilities and services (at project sites where such facilities and services are not available) for the housing, health, safety, welfare, and recreation of personnel employed by the Commission as it may deem necessary;

(6) with the consent of the agency concerned, utilize or employ the services or personnel of any Government agency or any State or local government, or voluntary or uncompensated personnel, to perform such functions on its behalf as may appear desirable;

(7) acquire, purchase, lease, and hold real and personal property as agent of and on behalf of the United States and to sell, lease, grant, and dispose of such real and personal property as provided in this Act; and

(8) without regard to the provisions of the Surplus Property Act of 1944 or any other law, make such disposition as it may deem desirable of (A) radioactive materials, and (B) any

other property the special disposition of which is, in the opinion of the Commission, in the interest of the national security.

(b) SECURITY.—The President may, in advance, exempt any specific action of the Commission in a particular matter from the provisions of law relating to contracts whenever he determines that such action is essential in the interest of the common defense and security.

(c) ADVISORY COMMITTEES.—The members of the General Advisory Committee established pursuant to section 2 (b) and the members of advisory boards established pursuant to subsection (a) (1) of this section may serve as such without regard to the provisions of sections 109 and 113 of the Criminal Code (18 U. S. C., secs. 198 and 203) or section 19 (e) of the Contract Settlement Act of 1944, except insofar as such sections may prohibit any such member from receiving compensation in respect of any particular matter which directly involves the Commission or in which the Commission is directly interested.

COMPENSATION FOR PRIVATE PROPERTY ACQUIRED

SEC. 13. (a) The United States shall make just compensation for any property or interests therein taken or requisitioned pursuant to sections 5 and 11. The Commission shall determine such compensation. If the compensation so determined is unsatisfactory to the person entitled thereto, such person shall be paid 50 per centum of the amount so determined, and shall be entitled to sue the United States in the Court of Claims or in any district court of the United States in the manner provided by sections 24 (20) and 145 of the Judicial Code to recover such further sum as added to said 50 per centum will make up such amount as will be just compensation.

(b) In the exercise of the rights of eminent domain and condemnation, proceedings may be instituted under the Act of August 1, 1888 (U. S. C., title 40, sec. 257), or any other applicable Federal statute. Upon or after the filing of the condemnation petition, immediate possession may be taken and the property may be occupied, used, and improved for the purposes of this Act, notwithstanding any other law. Real property acquired by purchase, donation, or other means of transfer may also be occupied, used, and improved for the purposes of this Act, prior to approval of title by the Attorney General.

JUDICIAL REVIEW AND ADMINISTRATIVE PROCEDURE

SEC. 14. (a) Notwithstanding the provisions of section 12 of the Administrative Procedure Act (Public Law 404, Seventy-ninth Congress, approved June 11, 1946) which provide when such Act shall take effect, section 10 of such Act (relating to judicial review) shall be applicable, upon the enactment of this Act, to any agency action under the authority of this Act or by any agency created by or under the provisions of this Act.

(b) Except as provided in subsection (a), no provision of this Act shall be held to supersede or modify the provisions of the Administrative Procedure Act.

(c) As used in this section the terms ''agency action'' and ''agency'' shall have the same meaning as is assigned to such terms in the Administrative Procedure Act.

JOINT COMMITTEE ON ATOMIC ENERGY

Sec. 15. (a) There is hereby established a Joint Committee on Atomic Energy to be composed of nine Members of the Senate to be appointed by the President of the Senate, and nine Members of the House of Representatives to be appointed by the Speaker of the House of Representatives. In each instance not more than five members shall be members of the same political party.

(b) The joint committee shall make continuing studies of the activities of the Atomic Energy Commission and of problems relating to the development, use, and control of atomic energy. The Commission shall keep the joint committee fully and currently informed with respect to the Commission's activities. All bills, resolutions, and other matters in the Senate or the House of Representatives relating primarily to the Commission or to the development, use, or control of atomic energy shall be referred to the joint committee. The members of the joint committee who are Members of the Senate shall from time to time report to the Senate, and the members of the joint committee who are Members of the House of Representatives shall from time to time report to the House, by bill or otherwise, their recommendations with respect to matters within the jurisdiction of their respective Houses which are (1) referred to the joint committee or (2) otherwise within the jurisdiction of the joint committee.

(c) Vacancies in the membership of the joint committee shall not affect the power of the remaining members to execute the functions of the joint committee, and shall be filled in the same manner as in the case of the original selection. The joint committee shall select a chairman and a vice chairman from among its members.

(d) The joint committee, or any duly authorized subcommittee thereof, is authorized to hold such hearings, to sit and act at such places and times, to require, by subpena or otherwise, the attendance of such witnesses and the production of such books, papers, and documents, to administer such oaths, to take such testimony, to procure such printing and binding, and to make such expenditures as it deems advisable. The cost of stenographic services to report such hearings shall not be in excess of 25 cents per hundred words. The provisions of sections 102 to 104, inclusive, of the Revised Statutes shall apply in case of any failure of any witness to comply with a subpena or to testify when summoned under authority of this section.

(e) The joint committee is empowered to appoint and fix the compensation of such experts, consultants, technicians, and clerical and stenographic assistants as it deems necessary and advisable, but the compensation so fixed shall not exceed the compensation prescribed under the Classification Act of 1923, as amended, for comparable duties. The committee is authorized to utilize the services, information, facilities, and personnel of the departments and establishments of the Government.

ENFORCEMENT

Sec. 16. (a) Whoever willfully violates, attempts to violate, or conspires to violate, any provision of sections 4 (b), 4 (e), 5 (a) (3), or 6 (b), shall, upon conviction thereof, be punished by a fine of not more than $10,000 or by imprisonment for not more than five years, or both, except that whoever commits such an offense with intent to injure the United States or with intent to secure an advantage to any foreign nation shall, upon conviction thereof, be punished by death or imprisonment for life (but the penalty of death or imprisonment for life may be imposed only upon recommendation of the jury and only in cases where the offense was committed with intent to injure the United States); or by a fine of not more than $20,000 or by imprisonment for not more than twenty years, or both.

(b) Whoever willfully violates, attempts to violate, or conspires to violate, any provision of this Act other than those specified in subsection (a) and other than section 10 (b), or of any regulation or order prescribed or issued under sections 5 (b) (4), 10 (c), or 12 (a) (2), shall, upon conviction thereof, be punished by a fine of not more than $5,000 or by imprisonment for not more than two years, or both, except that whoever commits such an offence with intent to injure the United States or with intent to secure an advantage to any foreign nation shall, upon conviction thereof, be punished by a fine of not more than $20,000 or by imprisonment for not more than twenty years, or both.

(c) Whenever in the judgment of the Commission any person has engaged or is about to engage in any acts or practices which constitute or will constitute a violation of any provision of this Act, or any regulation or order issued thereunder, it may make application to the appropriate court for an order enjoining such acts or practices, or for an order enforcing compliance with such provision, and upon a showing by the Commission that such person has engaged or is about to engage in any such acts or practices a permanent or temporary injunction, restraining order, or other order may be granted.

(d) In case of failure of refusal to obey a subpena served upon any person pursuant to section 12 (a) (3), the district court for any district in which such person is found or resides or transacts business, upon application by the Commission, shall have jurisdiction to issue an order requiring such person to appear and give testimony or to appear and produce documents, or both, in accordance with the subpena; and any failure to obey such order of the court may be punished by such court as a contempt thereof.

REPORTS

Sec. 17. The Commission shall submit to the Congress, in January and July of each year, a report concerning the activities of the Commission. The Commission shall include in such report, and shall at such other times as it deems desirable submit to the Congress, such recommendations for additional legislation as the Commission deems necessary or desirable.

DEFINITIONS

Sec. 18. As used in this Act—

(a) The term "atomic energy" shall be construed to mean all forms of energy released in the course of or as a result of nuclear fission or nuclear transformation.

(b) The term "Government agency" means any executive department, commission, independent establishment, corporation wholly or partly owned by the United States which is an instrumentality of the

United States, board, bureau, division, service, office, officer, authority, administration, or other establishment, in the executive branch of the Government.

(c) The term "person" means any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, the United States or any agency thereof, any government other than the United States, any political subdivision of any such government, and any legal successor, representative, agent, or agency of the foregoing, or other entity, but shall not include the Commission or officers or employees of the Commission in the exercise of duly authorized functions.

(d) The term "United States", when used in a geographical sense, includes all Territories and possessions of the United States and the Canal Zone.

(e) The term "research and development" means theoretical analysis, exploration, and experimentation, and the extension of investigative findings and theories of a scienific or technical nature into practical application for experimental and demonstration purposes, including the experimental production and testing of models, devices, equipment, materials, and processes.

(f) The term "equipment or device utilizing fissionable material or atomic energy" shall be construed to mean any equipment or device capable of making use of fissionable material or peculiarly adapted for making use of atomic energy and any important component part especially designed for such equipment or devices, as determined by the Commission.

(g) The term "facilities for the production of fissionable material" shall be construed to mean any equipment or device capable of such production and any important component part especially designed for such equipment or devices, as determined by the Commission.

APPROPRIATIONS

Sec. 19. There are hereby authorized to be appropriated such sums as may be necessary and appropriate to carry out the provisions and purposes of this Act. The Acts appropriating such sums may appropriate specified portions thereof to be accounted for upon the certification of the Commission only. Funds appropriated to the Commission shall, if obligated by contract during the fiscal year for which appropriated, remain available for expenditure for four years following the expiration of the fiscal year for which appropriated. After such four-year period, the unexpended balances of appropriations shall be carried to the surplus fund and covered into the Treasury.

SEPARABILITY OF PROVISIONS

Sec. 20. If any provision of this Act, or the application of such provision to any person or circumstances, is held invalid, the remainder of this Act or the application of such provision to persons or circumstances other than those as to which it is held invalid, shall not be affected thereby.

SHORT TITLE

Sec. 21. This Act may be cited as the "Atomic Energy Act of 1946".
Approved August 1, 1946.

DIVISION OF MINES PUBLICATIONS ISSUED SEPTEMBER 1, 1948 TO FEBRUARY 15, 1949*

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

Vol. 44, no. 4, October 1948, pp. 321-524, pls. 52-59, 20 figs. *Price 75¢.*

Contains: Economic aspects of mercury production in California, by C. R. King, pp. 327-334, 2 figs.; Current and recent mining activities in the Redding district (Colusa, Del Norte, Glenn, Humboldt, Lake, Lassen, Mendocino, Modoc, Shasta, Siskiyou, Tehama, Trinity Counties), by J. C. O'Brien, pp. 335-378, pls. 52-55; The spectrograph and polarograph, by John Herman, pp. 379-409, pls. 56-59, 18 figs.; Public Resources Code, pp. 411-415; U. S. Atomic Energy Commission announces program to stimulate production of domestic uranium, pp. 417-425; Publications of the California State Division of Mines, by Elisabeth L. Egenhoff, Beth Collins, and Mary-Louise Burgess, pp. 427-516; Index to volume 44, pp. 517-524.

Vol. 45, no. 1, January 1949, pp. 1-116, pls. 1-8, 4 figs. *Price 75¢.*

Contains: Annual report, Division of Mines, for the ninety-ninth fiscal year, July 1, 1947, to June 30, 1948, by Olaf P. Jenkins, pp. 7-29; Quicksilver deposits of the Oakville district, Napa County, California, by Philip F. Fix and C. Melvin Swinney, pp. 31-46, pls. 1-3, 2 figs.; Mines and mineral resources of Tuolumne County, California, by Clarence A. Logan, pp. 47-83, pls. 4-8; Barium, by W. B. Winston, pp. 85-97; Penn mine slag dump and mine water, Calaveras County, California, by Frank J. Wiebelt and Spangler Ricker (reprint), pp. 99-105, 2 figs.; Division of Mines publications issued September 1, 1948, to November 30, 1948, p. 107; Map symbols used in publications of the U. S. Geological Survey, pp. 109-116.

The following is included with report, or may be obtained alone: Map of western third of Tuolumne County, California, showing mining claims and prospects, scale ⅞″ = 1 mi. (approx.). *Price 25¢ (California residents please add 1¢ sales tax).*

Vol. 45, no. 2, April 1948, pp. 117-358, pls. 9-18, 2 figs. *Price 75¢.*

Contains: Water-flooding as a method of increasing California oil production (Part 1, Factors influencing the application of water-flooding), by Wilbur H. Somerton, pp. 123-202, 1 fig.; Mineral resources of Kern County, California, by W. B. Tucker, R. J. Sampson, and G. B. Oakeshott, pp. 203-297, pls. 9-18, 1 fig.; State geological surveys, by Wilson M. Laird, pp. 299-317; Industrial uses of limestone and dolomite, by Oliver Bowles and Nan C. Jensen, pp. 319-334; An Act for the development and control of atomic energy, pp. 335-356; Division of Mines publications issued September 1, 1948 to February 15, 1949, p. 357.

---

* Second supplement to Publications of the California State Division of Mines to September 1, 1948: California Jour. Mines and Geology, vol. 44, pp. 427-516, 1948. Reprint of the list of publications will be sent free upon request.

BULLETINS

140. Geology of the Tesla quadrangle, California, by Arthur S. Huey. 1948. 75 pp., 11 pls., 3 figs. *Price, cloth-bound, $2.25 (California residents please add 6¢ sales tax); paper-bound, $1.50 (California residents please add 4¢ sales tax).*

The following are included with report, or may be purchased (set of 3 sheets) alone: Colored geologic map on topographic base of Tesla quadrangle, scale 1:62,500; Topographic map of Tesla quadrangle with red overprint showing mineral deposits, section lines, and water-supply tunnel, scale 1:62,500; Structure sections across Tesla quadrangle. *Price, set of 3 sheets, 50¢ (California residents please add 1¢ sales tax).*

141. Geologic guidebook along Highway 49—Sierran gold belt—the Mother Lode country. 1948. 164 pp., 2 pls., 221 figs., 10 maps. *Price $1.00 (California residents please add 3¢ sales tax).*

Contains: Preface, by Olaf P. Jenkins, p. 7; Publications consulted, p. 8; Sierran roads of today and yesterday, by Dorothy G. Jenkins, pp. 9-12, 2 figs.; The discovery of gold in California, by Donald C. Cutter, pp. 13-17, 2 figs.; History of placer mining for gold in California, by Charles V. Averill, p. 19, 6 figs.; Sierra Nevada province, by Olaf P. Jenkins, p. 21, 1 fig.; Geologic history of the Sierran gold belt, by Olaf P. Jenkins, pp. 23-30, 11 figs.; History of mining and milling methods in California, by C. A. Logan, pp. 31-34, 1 fig.; Geologic maps and notes along Highway 49, by Oliver E. Bowen Jr. and Richard A. Crippen Jr., pp. 35-86, 42 figs., 10 maps; The formation of quartz veins, by John A. Burgess, pp. 87-88, 3 figs.; Mining on Carson Hill, by John A. Burgess, pp. 89-90; Survey of building structures of the Sierran gold belt, 1848-70, by Robert F. Heizer and Franklin Fenenga, pp. 91-164, 168 figs.

o

98921 11-48 2M

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES

MAP OF KERN COUNTY CALIFORNIA

SHOWING LOCATIONS
OF MINES AND PROSPECTS

LIST OF MINES AND PROSPECTS SHOWN ON MAP OF KERN COUNTY, CALIFORNIA

ANTIMONY

Map No.	Mine	Sec.	Location T.	Location R.	B&M
1	Alice antimony	2 (?)	28S	32E	MD
2	Amalia	5	[illegible]	[illegible]	[illegible]
3	Antimony Consolidated Mines	5, 6	30S	36E	MD
4	Antimony Peak (San Emigdio)	9, 10	9N	21W	SB
5	Jennette-Grant	10	28S	34E	MD
6	Mahary and Houghtawoth group	4	10N	15W	SB
7	Studhorse Canyon	5	31S	33E	MD
8	Tom Moore	24	27S	33E	MD
9	Top of World	34	30S	32E	MD
10	Wiggins	8	31S	33E	MD

ARSENIC

Map No.	Mine	Sec.	Location T.	Location R.	B&M
11	Contact	10	10N	15W	SB

COPPER

Map No.	Mine	Sec.	Location T.	Location R.	B&M
12	Apache (Holland)	32	28S	39E	MD
13	Copperola group	12, 13	29S	38E	MD
14	Copper Basin group	15	29S	38E	MD
15	French group	3	29S	38E	MD
16	Gold Badger group (Zandra)	12	29S	38E	MD
17	Orange Blossom	6	30S	38E	MD
18	Silverado group	9	27S	33E	MD

GOLD

Map No.	Mine	Sec.	Location T.	Location R.	B&M
19	Amalie	22	30S	33E	MD
20	American Golden Eagle	2, 10	28S	32E	MD
21	Amy (Gold State)	5, 32	29S 28S	34E 34E	MD MD
22	Baltic	1	30S	40E	MD
23	Barbarossa	29	30S	33E	MD
24	Barnett	16	30S	40E	MD
25	Beauregard (see also Big Blue)	28	25S	33E	MD
26	Beauregard Extension	28	25S	33E	MD
27	Beehive	33 (?)	28S	40E	MD
28	Beryl group	30	29S	37E	MD
29	Big Blue (includes Beauregard, Lady Belle, and Sumner)	28, 33	25S	33E	MD
30	Big Dyke	1, 2	30S	40E	MD
31	Big Gold (West [illegible]	3, 4	30S	40E	MD
32	Black Hawk	[illegible]	[illegible] 30S	[illegible] 40E	[illegible]
33	Black Mountain	10	29S	39E	MD
	Blue Eagle (see [illegible] Queen)				
34	Blue Jay	31	28S	34E	MD
35	Blue Mountain (Dranol)	11, 12 14	25S	29E	MD
36	Bond Buyer group	1	30S	37E	MD
37	Bowman (French Meadows)	20	28S	34E	MD
38	Bright Star	10	28S	34E	MD
39	Bright Star	12	25S	29E	MD
40	Bryan	19	29S	34E	MD
41	Buckboard	10	30S	40E	MD
42	Bull Run (see Big Blue)				
43	Bully Boy	11, 12	30S	40E	MD
44	Burning Moscow	19	28S	35E	MD
45	Burton, Brite, and [illegible]	16	10N	13W	SB
46	Butte	36	29S	40E	MD
47	Butte Wedge (see Consolidated Mines)				
48	Cactus Queen	17	10N	13W	SB
49	Caldwell	18	26S	33E	MD
49A	Chamberlain group (see also Goler Canyon placers)	11	29S	39E	MD
50	Chief	22	27S	29E	MD
51	Claraville placers	27, 34 4	28S 29S	34E 34E	MD MD
52	Collar Button	10	28S	34E	MD
53	Commonwealth (see Big Blue)				
54	Confidence group	31 (?)	29S	38E	MD
55	Consolidated Mines	35	29S	40E	MD
56	Contest (see Big Blue)	28	25S	33E	MD
57	Croesus group (Little Charlie)	6	29S	38E	MD
58	Cunningham group (placer)	1, 2 27	29S 28S	39E 39E	MD
59	David King group	10	29S	34E	MD
60	Dead River placer	17	26S	33E	MD
61	Dead Tree	21, 22	29S	34E	MD
62	Deer Hunter	20	30S	34E	MD
63	Dearborn	26	29S	34E	MD
64	Donnie	6	29S	34E	MD
65	Double Standard	5	10N	12W	SB
66	Drunkard's Dream	17, 18	28S	33E	MD
67	Echo, Elephant, Gray Eagle	6	10N	12W	SB
68	Ederl group (McKeadney, [illegible])	[illegible], 9, 10	28S	32E	[illegible]
69	Elbow and Boulder (placer)	33	27S	31E	MD
70	Elephant (see Echo, Gray Eagle, etc.)				
71	Elston	8	29S	31E	MD
72	Esperanza	5, 6	29S	35E	MD
73	Eureka	6	10N	12W	SB
74	Exposed Treasure and Desert Queen	32	11N	12W	SB
75	Ferris (Golden or Jack Rabbit)	34	30S	32E	MD
76	Fine Gold (placer)	12 (?)	29S	39E	MD
77	Four Jacks	5 (?)	10N	12W	SB
78	G. B.	1	30S	40E	MD
79	Gem	5	28S	31E	MD
80	Glen Olive	33	27S	33E	MD
81	Gold Bar (placer)	33	27S	31E	MD
82	Gold Bug	35	27S	40E	MD
83	Gold Cross (Eclipse, Edith, Paris, Standard)	28	30S	33E	MD
84	Gold Crown	11, 12	30S	40E	MD
85	Gold Hill	21, 22	28S	34E	MD
86	Golden (see Ferris)				
87	Gold King	4 (?)	28S	31E	MD
88	Gold Pass	35 (?)	27S	40E	MD
89	Gold Peak (Zada)	28	30S	33E	MD
90	Gold Peak	6	29S	36E	MD
91	Gold Standard	12	28S	33E	MD
92	Golden Queen (Silver Queen, Queen Esther, Lodestar or Starlight, and Soledad Extension)	6, 7	10N	12W	SB
93	Goler Canyon placers	1 2, 3 10, 11	29S	39E	MD
94	Good Hope	35	29S	40E	MD
95	Good Luck	16	27S	29E	MD
96	Granite King	28	29S	36E	MD
97	Gray Eagle	6	10N	12W	SB
98	Great Unknown (See Beryl No. 28)				
99	Greenhorn Caves placer	12, 13 24, 19	27S 27S	31E 32E	MD
100	Grubstake placer	20 (?)	29S	38E	MD
101	Gum Tree	32	11N	12W	SB
102	Gwynne (Gwynne-Jennette, Dearborn, and Mace)	21 22	29S	34E	MD
103	Hoegee (Haeger)	15	9N	13W	SB
104	Hanover	21 22	29S	34E	MD
105	Helene Galvin	5	28S	31E	MD
106	Hub	4	31S	35E	MD
107	Huntington	35 (?)	27S	40E	MD
108	Iconoclast	25	27S	33E	MD
109	French Meadows (see Bowman)				
110	Illinois and Golden Bell	16	27S	33E	MD
111	Indian Queen	15	27S	29E	MD
112	Indian Wells Valley	26 (?)	27S	40E	MD
113	Iron Hat	1	29S	39E	MD
114	Jenney placer (see also Goler Canyon placers)	2, 3 10, 11 23, 24 25, 26	29S	39E	MD
		4, 5 8, 9 10, 17 18, 19 20, 21 30	29S	40E	MD
115	Jeff Davis (see Big Blue)				
116	Jennette-Grant	4, 10	28S	34E	MD
117	Jennette (Gwynne-Jennette)	22	29S	34E	MD
118	Joe Walker	7, 12	29S	33E	MD
119	Josephine	34	27S	33E	MD
120	Josephine	2, 3 4, 5 8	25S	29E	MD
121	Juan Dosie	22	30S	33E	MD
122	Jumbo	2	29S	39E	MD
123	Karma	6	10N	12W	SB
124	Kelso Creek placers	16	28S	35E	MD
125	Keyes	26	26S	32E	MD
126	King Solomon	35	29S	40E	MD
127	King Solomon (Pleasant View)	9, 10	28S	33E	MD
128	La Crosse	11	30S	40E	MD
129	Ladd	36	11N	12W	SB
130	Lady Belle (see Big Blue)	28	25S	33E	MD
131	Laurel	26	27S	33E	MD
132	Lehigh Valley	22 (?)	22S	40E	MD
133	Lida (see Tropico)	11	9N	13W	SB
134	Little Angel	2	28S	32E	MD
135	Little Bonanza	35	26S	32E	MD
136	Little Belle	35	29S	40E	MD
137	Little Joe	29	28S	34E	MD
138	Locarno	SE¼ 21, 28	29S	34E	MD
139	Lone Star	7, 8	28S	34E	MD
140	Long Tom	21	27S	29E	MD
141	Lost Keys	34 (?)	27S	40E	MD
142	Lucky Boy (see also La Crosse)	11	30S	40E	MD
143	Maltby placer	20 (?)	25S	29E	MD
144	Mammoth	35	26S	32E	MD
145	Master Key	36	29S	40E	MD
146	McKidney	9	28S	32E	MD
147	Middle Butte	SW¼ 16	10N	13W	SB
148	Milwaukee	16	9N	13W	SB
149	Minnehaha	2	29S	40E	MD
150	Mohawk-Budey	23	29S	36E	MD
151	Monarch (Extension Ajax)	5	10N	12W	SB
152	Nellie Dent (see Big Blue)	28	25S	33E	MD
153	North Sumner (see also Big Blue)	28	25S	33E	MD
154	Norden placer	22	29S	40E	MD
155	Norman placer	36	29S	40E	MD
156	Old Cowboy	28	30S	33E	MD
157	Operator Consolidated (Phoenix, Operator Divide)	35	29S	40E	MD
158	Ophir	11	28S	32E	MD
159	Opportunity	35 (?)	26S	33E	MD
160	Oro Fino (see Summit placers)	1, 12	29S	40E	MD
161	Orphan Girl	12	29S	40E	MD
162	Pearl Wedge	11	29S	40E	MD
163	Pennsylvania	35	26S	32E	MD
164	Phoenix (see Operator Consolidated)				
165	Pine Tree (American)	4	11N	15W	SB
166	Pinmore	25, 36	29S	40E	MD
167	Piute (see Tropico)	11	9N	13W	SB
168	Piute Consolidated	13	28S	34E	MD
169	Polar Bear	29	27S	33E	MD
170	Poso	30, 31	27S	28E	MD
171	President	4	27S	32E	MD
172	Pyramid	1 (?)	29S	40E	MD
173	Queen Esther (see Golden Queen)	6	10N	12W	SB
174	Rand	3	28S	32E	MD
175	Rand Gold Dredging Associates	23, 24	29S	40E	MD
176	Rand placers	6, 9	29S	39E	MD
177	Rattlesnake group	32 (?)	29S	38E	MD
178	Red Hill	21	25S	33E	MD
179	Red Wing	26, 35	27S	40E	MD
180	Reform	1, 12	28S	33E	MD
181	Ricardo placers	2, 35	29S 30S	37E	MD
182	Riches and Wealth placer	19	26S	32E	MD
183	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
184	Rose	31	26S	32E	MD
185	Ruby	9, 16 17	29S	31E	MD
186	Pustler and San Diego	2	29S	40E	MD
187	Sailor Boy (Ben Hur)	6	10N	12W	SB
188	San Antonio	22, 23	29S	36E	MD
189	Santa Ana (Napoleon)	11	30S	40E	MD
190	Sidney (White)	16, 17	30S	40E	MD
191	Sky Line	15 (?)	31S	36E	MD
192	Southern Cross (Uncle Sam)	3, 10	28S	40E	MD
193	Stanford	1, 11 12	30S	40E	MD
194	Stellar	23	26S	40E	MD
195	St. Charles	33 (?)	27S	32E	MD
196	St. John	33 3, 4	28S 29S	35E 35E	MD MD
197	St. Lawrence	1	30S	40E	MD
198	Summit gold placers (Summit diggings)	1, 2 6	29S 29S	40E 41E	MD MD
199	Sumner and North Extension	28	25S	33E	MD
200	Sunrise-Jenny Lind and New World	10	28S	32E	MD
201	Sunset	10	27S	32E	MD
202	Sunshine	11	30S	40E	MD
203	Surprise group	29	28S	34E	MD
204	Trestle	18	29S	34E	MD
205	Tropico	10, 11 14, 15	9N	13W	SB
206	Uncle Sam (see also Southern Cross)				
207	Urbana and Frank (see Big Blue)	28	25S	33E	MD
208	Valley View	3, 4	28S	33E	MD
209	Voss Consolidated	1	30S	37E	MD
210	Wall Street group	18	28S	34E	MD
211	Wall Street	35	27S	40E	MD
212	Warrington (Little Angel)	3 (?), 4	28S	32E	MD
213	Watkins group	35	28S	39E	MD
214	Wedge (see Exposed Treasure)	32	11N	12W	SB
215	White (see Sidney)				
216	White Star	11	22S	32E	MD
217	White Star	28 (?)	27S	40E	MD
218	Whitmore	32	11N	12W	SB
219	Windy	34	29S	40E	MD
220	Yellow Aster	2, 3 34, 35	29S 30S	40E 40E	MD MD
221	Yellow Boy	18	28S	34E	MD
222	Yellow Dog	29, 32	11N	12W	SB
223	Yellow Dog Extension	35	11N	12W	SB
224	Yellow Treasure	35	27S	40E	MD
225	Zenda	30	30S	33E	MD

IRON

Map No.	Mine	Sec.	Location T.	Location R.	B&M
226	Iron Mountain	10, 15	26S	29E	MD
227	Mount Breckenridge	4	29S	31E	MD
228	San Emidio	17	9N	21W	SB

LEAD

Map No.	Mine	Sec.	Location T.	Location R.	B&M
229	Beehive	32 (?)	28S	40E	MD
230	Black Hawk group	28	30S	33E	MD
231	Churchill	20	28S	40E	MD

SILVER

Map No.	Mine	Sec.	Location T.	Location R.	B&M
232	Hummer	30 (?)	28S	40E	MD
233	Mizpah-Montana	1, 6	30S	40E 41E	MD
234	Mizpah-Nevada	1, 6	30S	40E 41E	MD
235	Monarch Rand	1, 12	30S	40E	MD
236	Rand Contact	7, 12 13, 18	30S 30S	40E 41E	MD MD
237	Rattlesnake group	5	29S	38E	MD
238	St. Lawrence Rand	1	30S	40E	MD
239	Summit group	15	26S	33E	MD
240	Treasure Hill	1	30S	40E	MD
241	White Horse	1	30S	40E	MD

QUICKSILVER

Map No.	Mine	Sec.	Location T.	Location R.	B&M
242	Cuddeback cinnabar mine	27	31S	32E	MD

TIN

Map No.	Mine	Sec.	Location T.	Location R.	B&M
243	Hogan-Mallery (Meek-Hogan)	25	9N	18W	SB

TUNGSTEN

Map No.	Mine	Sec.	Location T.	Location R.	B&M
244	Bald Eagle	31	26S	34E	MD
245	Bald Mountain	14	27S	32E	MD
246	Basin View	31 (?)	29S	33E	MD
247	Big Lode	32	26S	34E	MD
248	Big Tungsten	3	30S	40E	MD
249	Blue Point	10, 11 14, 15	30S	31E	MD
250	Buckhorn (Why Not)	19	25S	32E	MD
251	Cadillac	7, 8	25S	32E	MD
252	Consolidated Mines	35	29S	40E	MD
253	Cow Canyon	12 (?)	25S	36E	MD
254	[illegible]	[illegible]	29S	[illegible]	[illegible]
255	El Diablo (Trojan)	31	25S	33E	MD
256	Fidgie group	23	27S	33E	MD
257	F O B	1 (?)	26S	37E	MD
258	Four K group	26	27S	32E	MD
259	General MacArthur group	2	10N	15W	SB
260	Gold Wash (Ben Hur)	1	30S	40E	MD
261	Gribble group	19	25S	32E	MD
	Gwynne and Jennette (see 102 under Gold)	21, 22	29S	34E	MD
262	Herschel Kelso	17	25S	32E	MD
263	Hi Peak	10, 15	26S	38E	MD
264	High Power	20	25S	32E	MD
265	Howe group	23	27S	32E	MD
266	Ideal	20, 21	25S	31E	MD
267	King (Sierra, Herschel, Owl, Ideal)	17, 20	25S	32E	MD
268	Little Dick and Good Hope	23	25S	33E	MD
269	Little Wonder	33	28S	32E	MD
	Locarno-Simon group (see 138, Locarno, under Gold)				
270	Major (Rand, Ione, and Sweet)	19, 20	25S	32E	MD
	Minnehaha (see 149 under Gold)				
271	Mintern	24	25S	33E	MD
272	Miranda	1	26S	33E	MD
	Monarch Rand (see 235 under Silver)	1, 12	30S	40E	MD
273	Mountain View	26	28S	32E	MD
274	Naja	1	29S	33E	MD
275	Owl	17	25S	32E	MD
	Pine Tree (see 165 under Gold)				
276	Plasse	12	27S	34E	MD
277	Play Boy	1	26S	33E	MD
278	Prosperity	35	27S	32E	MD
279	Pyarin group (Indian Wells)	1	26S	37E	MD
280	Radcliffe	12	30S	40E	MD
281	Royal Bohee (Royal Boyn)	9	30S	49E	MD
282	Sierra	20	25S	32E	MD
	Stanford (see 193 under Gold)				
283	Star Dust and Black Cat	1	27S	34E	MD
284	Summit Lime Company		11N 12N	15W	SB
285	Sunset group (Hawk mine)	6	30S	40E	MD
286	Syrus Canyon group	35	25S	33E	MD
287	Top of the World (see 9)	34	30S	32E	MD
288	[illegible]	[illegible]	27S	[illegible]	[illegible]
289	Tungsten Chief (Wall Street group, Ophir-[illegible])	26, 27 33	28S	32E	MD
290	Tungsten Hill	3	28S	32E	MD
291	Tungsten King	26	27S	32E	MD
292	Tungstore mine No. 2	11	25S	29E	MD
293	Tungsten Queen	30, 31	25S	33E	MD
294	Williams Ranch	16	29S	33E	MD
295	Yellow Aster (see under Gold)				

ZINC

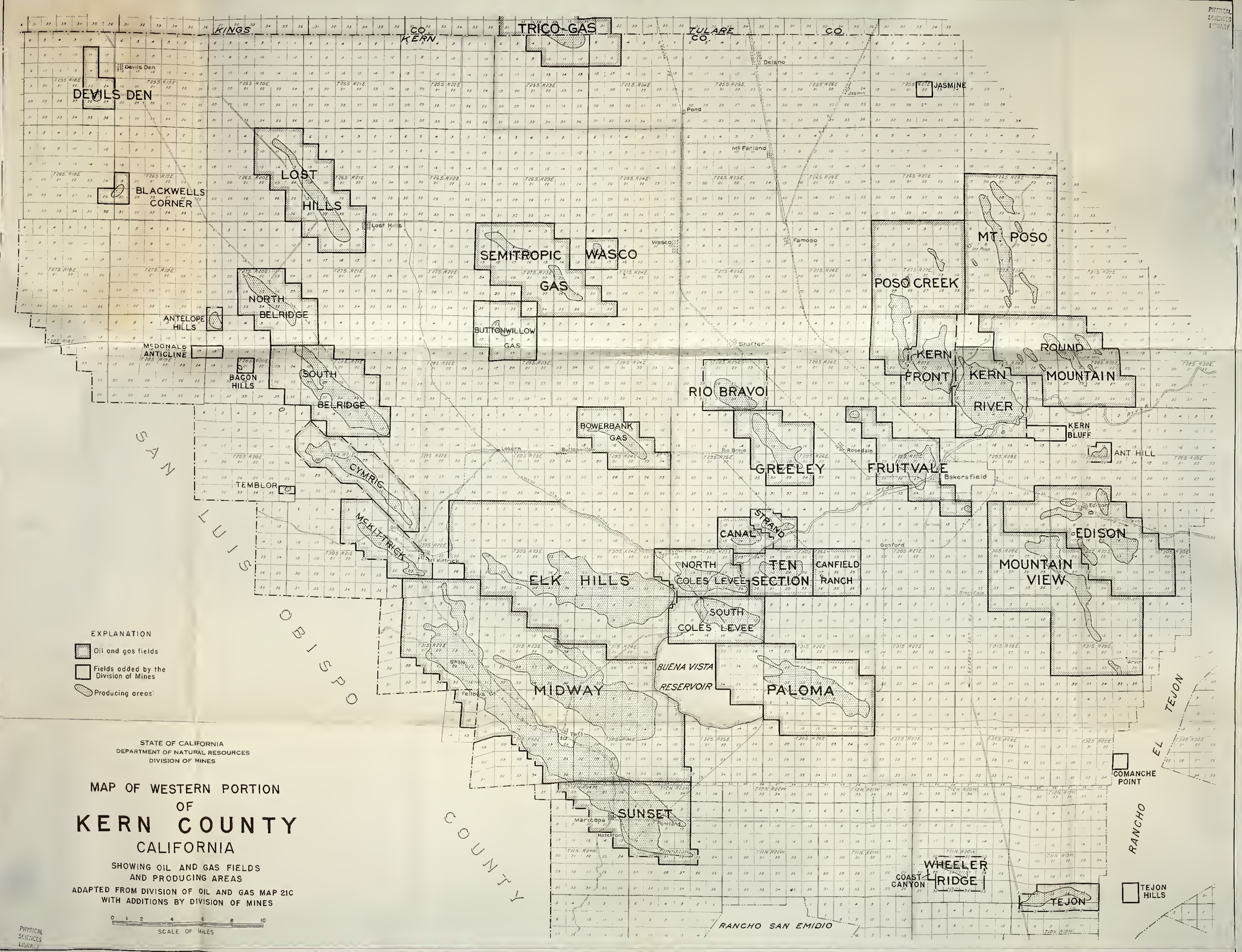
Map No.	Mine	Sec.	Location T.	Location R.	B&M
296	Tejon Ranch (Cully and Hoyes, Kelso)	35 (?)	9N	18W	SB

NON-METALS

Map No.	Mine	Sec.	Location T.	Location R.	B&M
297	San Emigdio asbestos	32 (?)	9N	21W	MD
298	Pacific Coast borax	app 4500 acres	11N	8W	SB
298A	Sukow borax (see Pacific Coast borax, 298)	14	11N	8W	SB
298B	Western borax mine (part of Pacific Coast borax mine, 298)	5½, 24	11N	8W	SB
299	Amargo bentonite deposit	26	11N	8W	SB
300	Iron Canyon bentonite	19 (?)	29S	38E	MD
301	Antelope Materials Co. (clay)	30, 32	9N	10W	SB
302	California fullers earth	14	27S	28E	MD
303	Duran bentonite deposit	21 (?)	28S	40E	MD
304	Filliol clay	2, 34	32S 31S	34E 34E	MD MD
305	Jawbone Canyon Clay (Williams)	27, 34	30S	36E	MD
306	Koehn clay	28 (?)	29S	38E	MD
307	McKinney clay	28 (?)	29S	38E	MD
308	Muroc clay	2, 3	11N	9W	SB
309	Muroc silt deposit (clay)	21, 22 23	10N	9W	SB
310	Riley clay	19	9N	11W	SB
311	Rosamond clay	11	9N	13W	SB
312	Webb clay	NW¼ 10	9N	13W	SB
313	Snow-White clay	30	29S	32E	MD
314	Stevens clay	9 (?)	29S	38E	MD
315	White Bluff clay	18	29S	38E	MD
316	White Swan clay	14	30S	36E	MD
317	White Ridge dolomite	25	9N	20W	SB
318	Rosamond feldspar (Townsend) (feldspar, [illegible])	[illegible] 6	9N	12W	SB
319	Cottonwood Creek gypsum	21, 22 28, 29	29S	[illegible]	MD
319A	Crystal Gypsum Co.	27, 34 35	32S	27E	MD
320	Holloway gypsum	3, 10 11, 13 14, 15 24	26S	20E	MD
321	Monolith gypsum	31	30S	22E	MD
322	Mojave Desert gypsum	28	30S	38E	MD
322A	Pacific Gypsum Co.	26	32S	27E	MD
323	Antelope Valley marble	2	9N	17W	SB
324	Cuddy Canyon limestone	10	9N	20W	SB
325	Erskine Creek (limestone)	(?)	27S	33E	MD
326	Isabella limestone		26S 27S	33E 34E	MD
327	Monolith Portland Cement Co. (limestone, cement)	14	32S	33E	MD
328	Summit limestone (see 284)		11N 12N	15W	SB
329	Union lime	1720 acres	12N	15W	SB
330	Bissell magnesite	11	10N	10W	SB
331	Black Eagle and Gray Eagle (perlite)	4	29S	38E	MD
332	Black Mountain pumice	32	29S	38E	MD
333	Calsilco deposit (Holly cleanser) (volcanic ash)	33, 4	28S 29S	38E 38E	MD
334	Cudahy silica (Dutch Cleanser) (volcanic ash)	7	29S	38E	MD
335	Opal pumice	4	29S	39E	MD
336	Parroll and Allec silica (volcanic ash)	30 (?)	29S	38E	MD
337	White Castle pumicite	32	28S	39E	MD
338	Williams pumicite deposit	32	28S	39E	MD
339	Long Beach Salt Company	1, 11	30S	38E	MD

PHYSICAL SCIENCES LIBRARY

PHYSICAL SCIENCES LIBRARY



EXPLANATION

- ▨ Oil and gas fields
- ☐ Fields added by the Division of Mines
- ▨ Producing areas

STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES

MAP OF WESTERN PORTION OF KERN COUNTY CALIFORNIA

SHOWING OIL AND GAS FIELDS
AND PRODUCING AREAS

ADAPTED FROM DIVISION OF OIL AND GAS MAP 21C
WITH ADDITIONS BY DIVISION OF MINES

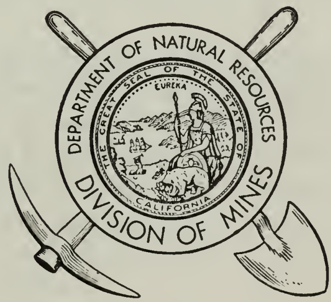
0 1 2 4 6 8 10
SCALE OF MILES

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

Vol. 45 JULY 1949 No. 3

CALIFORNIA JOURNAL
OF
MINES AND GEOLOGY



STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
OLAF P. JENKINS, Chief

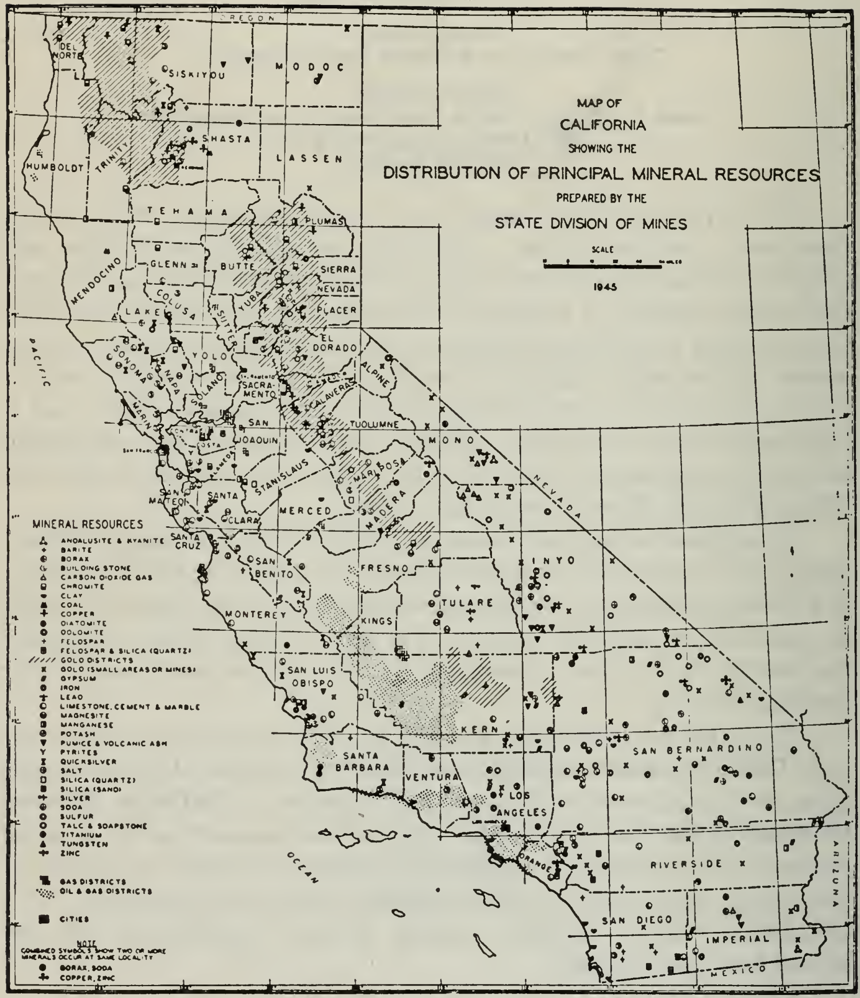
Headquarters
Third Floor, Ferry Building, San Francisco 11

District Offices
State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Box 445, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines are the quarterly **California Journal of Mines and Geology,** issued in January, April, July, and October of each year, and a series of **Bulletins. Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of publications will also be sent free upon request.


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES
SCALE
1945
MINERAL RESOURCES
ANDALUSITE & KYANITE
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY
BORAX, SODA
COPPER, ZINC
OREGON
DEL NORTE
SISKIYOU
MODOC
SHASTA
LASSEN
HUMBOLDT
TRINITY
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
NEVADA
MENDOCINO
COLUSA
YUBA
PLACER
LAKE
SUTTER
EL DORADO
SONOMA
YOLO
ALPINE
NAPA
SOLANO
SACRAMENTO
CALAVERAS
MARIN
SAN JOAQUIN
TUOLUMNE
COSTA
ALAMEDA
MONO
SAN MATEO
SANTA CLARA
STANISLAUS
MARIPOSA
SANTA CRUZ
MERCED
MADERA
NEVADA
SAN BENITO
FRESNO
INYO
MONTEREY
KINGS
TULARE
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
MEXICO
ARIZONA
PACIFIC
OCEAN

CONTENTS

Page

Water-Flooding as a Method of Increasing California Oil Production, Part 2, by Wilbur H. Somerton ---------- 363

Mines and Mineral Resources of Butte County, California, by J. C. O'Brien ---------- 417

Roofing Granules in the Southwest, by Stuart H. Ingram ---------- 455

The Western Pulp and Paper Industry as a Consumer of Chemicals, by R. G. Mispley ---------- 459

Mining Law in Recent Years, by William E. Colby ---------- 465

Ione-Carbondale Clays, Amador County, California, by F. T. Johnson and Spangler Ricker ---------- 491

PLATES

Plate 19. *A*, Butte County gravel plant, East Biggs, Butte County. *B*, Butte Creek Rock Company sand and gravel plant, Butte County. *C*, Central sand and gravel plant, on Dry Creek, Butte County ---------- 420-421

20. *A*, Henry J. Kaiser Company gravel plant south of Oroville, Butte County. *B*, Lancha Plana Gold Dredging Company dredge No. 3, on Butte Creek east of Chico, Butte County ---------- 420-421

21. *A*, Surcease (Big Bend) mill, Butte County. *B*, Surcease mine, plant yard ---------- 420-421

22. *A*, Yuba Consolidated Gold Fields bucket-line dredge No. 1, Oroville district, Butte County. *B*, Yuba Consolidated Gold Fields dredge No. 3, Oroville district, Butte County ---------- 420-421

23. Map showing mines and mineral deposits of Butte County, California ---------- In pocket

WATER-FLOODING AS A METHOD OF INCREASING CALIFORNIA OIL PRODUCTION *

By Wilbur H. Somerton **

OUTLINE OF REPORT

Page
Part 2—A survey of California conditions relative to the application of water-flooding 363
Introduction 363
History of water-flooding in California 364
Richfield experimental flooding project 364
Dominguez water-flooding project 365
Greeley waste-water disposal project 365
Water injection at Lost Hills 366
Summary 367
Characteristics of California oil fields 367
Table 1, Physical characteristics of California oil fields 368
Table 2, Geological and mineralogical characteristics of California oil fields 369
Table 3, Water and oil characteristics and production from California oil fields 370
Summary 416

PART 2

A SURVEY OF CALIFORNIA CONDITIONS RELATIVE TO THE APPLICATION OF WATER-FLOODING

Introduction

A review of the general principles involved in the water-flooding method of secondary recovery from oil fields was presented in the first part of this report.* Application of these principles is a formidable task. The unfortunate chasm existing between theory and practice is apparent in past and even in current water-flooding operations. This report represents, in part, an attempt to bridge the gap.

When California operators find it necessary to turn to secondary methods of oil recovery to meet increasing demands, they will be faced with an acute lack of past experience in this highly technical endeavor. Most other oil-producing regions in this country have built up a background of field and laboratory experience in water-flooding which will aid operators in initiating new projects. There is an almost complete lack of such experience in California and, although the general principles developed in other regions may be applicable, the dissimilar conditions encountered in most of the oil fields of this state will limit specific application of this experience. California operators might proceed on a trial-and-error basis, the common means of advancing water-flooding knowledge heretofore, but that such will probably not be the case is indicated by the hesitancy of operators to engage in experimental field work. Although ultimately a certain amount of field experimentation will be necessary, a thorough engineering study will reduce the expense and dangers inherent in trial-and-error work.

Such a study is not only imperative from the standpoint of good engineering practice but it is also important from the legal aspects involved.

---

* Part 2, *A Survey of California Conditions Relative to the Application of Water-Flooding*, is the second of three articles by Mr. Somerton on *Water-Flooding as a Method of Increasing California Oil Production*. Part 1, *Factors Influencing the Application of Water-Flooding*, was published in the California Journal of Mines and Geology, vol. 45, no. 2, for April 1949; Part 3, *Current and Proposed Water-Flooding Research in California*, will be issued in the California Journal of Mines and Geology, vol. 45, no. 4, for October 1949.

** Assistant Professor of Petroleum Engineering, University of California, Berkeley.

The great diversity of land ownership in most California fields will make it essential that operators present a sound argument in favor of water-flooding to the lessors before experimental projects are initiated.

As a preliminary to this study, a broad survey of the reservoir conditions encountered in California oil fields is presented in this report in the form of a series of tables depicting the most important reservoir conditions. From these data a comparison can be made between the characteristics of California fields and fields in other regions where water-flooding has been successful. Similarities might indicate certain principles and practices employed in other areas which might be applied to California fields. Dissimilarities between the characteristics of California fields and these other fields will indicate the research problems which must be investigated before water-flooding can be successfully applied. A research program must be developed and planned so as to give results which may be used in field operations without excessive field experimentation. The final step in the study would involve a detailed analysis of each field to determine the applicability of water-flooding in light of the above information.

History of Water-Flooding in California

Water-flooding operations in California have been restricted to experimental projects in four fields. These projects have been conducted on a very small scale, none involving more than two water-injection wells. In addition, they were either discontinued or have been in progress for such a short time that significant results have not yet been obtained.

The following paragraphs summarize the limited information available on these projects.

Richfield Experimental Flooding Project

Because of the predicted low ultimate recovery from the Chapman zone of the Richfield field (22 percent), an experimental water-injection project was initiated by the Union Oil Company to determine whether recovery might be increased by this method.

The reservoir data for this zone have been published by Babson, Sherborne, and Jones.[1] The Chapman zone is the upper of two producing intervals in the field and is found at depths of 3000 to 3700 feet. The sand is about 400 feet thick at the top of the structure but thins laterally as it interfingers with shale members near the margin of the zone. The sand is described as medium grained, friable, poorly sorted, and generally argillaceous. The average porosity of the interval selected for injection is 29.1 percent, the permeability to air about 422 millidarcys, and interstitial water content approximately 37 percent. The gravity of the oil averages about 19° A.P.I., and its viscosity at reservoir conditions is approximately 50 centipoises. The expulsive force in the zone is the expansion of dissolved gas; water encroachment is only a minor consideration.

A thin sand body within the zone, about 38 feet thick, was selected for the flooding tests. An injection well was drilled between two producing wells near the edge of the field. This well was completed with $5\frac{1}{2}$-inch pipe, cemented through the zone, and gun perforated. The well was allowed to produce for 3 weeks; it was then washed with acid, and again allowed to produce for several more weeks. At the end of this period the rods and tubing were pulled and $2\frac{1}{2}$-inch cement-lined tubing was run in the well.

---

[1] Babson, E. C., Sherborne, J. E., and Jones, P. H., An experimental water flood in a California oil field: Am. Inst. Min. Eng. Trans., vol. 160, pp. 25-33, 1945.

The water used for injection came from the two productive zones in the field. This water had a total salt content of somewhat less than 11,000 p.p.m., the major part of which was sodium chloride. Preliminary tests showed this water to contain considerable flocculable material and to exhibit a demand for oxygen. The treating method employed consisted of primary flocculation with alum, chlorination, secondary flocculation, and final filtration. It has been noted that upon standing, the treated water developed plugging tendencies. This is attributed to both organic and inorganic material. Nevertheless, the water has been injected successfully without additional treatment.

Injection was commenced March 29, 1944, at a low pressure and a low rate. The pressures and volume were increased so that by September 1944, 3,909 barrels of water per month were being injected at a pressure of 812 pounds per square inch. This represents about 3.5 barrels per foot of sand per day. The oil production in one of the adjacent wells increased during this period from 7 to 30 barrels and the water from 1 to 40 barrels per day.

After 33 months of operation some 216,972 barrels of water had been injected, of which 41,598 barrels were believed to have been produced through surrounding wells. Injection rates at the end of 1946 averaged 300 barrels of water per day at a pressure of 1000 pounds per square inch. This represents about 7.9 barrels per foot of sand per day. One producing well was abandoned when the water cut increased to 94 percent, attributable to the water injection. It was estimated that 22,180 barrels of extra oil had been produced up to the end of 1946 because of water injection.[2]

By the end of 1947, a total of 326,900 barrels of water had been injected at a rate of about 300 barrels per day and at a pressure of 700 pounds per square inch. Four wells, one as much as 900 feet from the injection well, have been affected by the flooding operations. The total daily oil production rate from these four wells has increased from 58 barrels per day at the time the project was first initiated to 198 barrels per day during December 1947. During the same period, water production has decreased from 233 barrels per day to 198 barrels per day.[3]

Since cost figures are not available, it is difficult to judge the financial success of the project. Nevertheless, this work has demonstrated that water can be injected into the reservoir at a sustained rate and that this water is capable of displacing considerable oil therefrom. The company has announced plans not only to continue the project but to increase its scope.

Dominguez Water-Flooding Project

The Union Oil Company has commenced development work on a second project, in the Dominguez field. Although no information has been released to date, it is believed that this project will be much more extensive than the one at Richfield, and may involve several injection wells.

Greeley Waste-Water Disposal Project

A water-injection project in the Greeley field was instituted as a means of disposal of waste water. The presence of an active edgewater drive became apparent early in the life of this field. Edge wells went to water rapidly and the water movement increased up dip until all wells were producing some water. Selective plugging attempts were not effective in reducing water production. Because of the agricultural activity in the area, disposal of the ever-increasing water production became an acute problem. In 1943 it was decided to inject waste water into the producing zone, and two edge wells, which had gone completely to water, were selected for this purpose.

---

[2] Summary of operations, California oil fields: California Div. Oil and Gas, Ann. Rept., vol. 32, no. 2, pp. 39-40, 1946.

[3] Summary of operations, California oil fields: California Div. Oil and Gas, Ann. Rept., vol. 33, no. 2, p. 44, 1947.

The depth of the Stevens producing zone is about 7700 feet and the thickness about 100 feet. The sands are lenticular, and interfinger with shale beds. The sand zones are fairly uniform, and are described as ''firm, friable, medium to coarse grained with grit grains and a few thin streaks of sandy, micaceous, dark gray shale.''[4] The porosity of the sand zones averages 21 percent.

The oil produced from the zone has a gravity of 32 to 36° A.P.I. As this oil was known to deposit bitumen, it was thought that this substance might have plugged the pores of the formation near the well bore. Solvent treatment of an injection well, however, produced no beneficial results.

The water produced from the Stevens zone had a total salt content of about 21,000 p.p.m., and a high bicarbonate concentration. The water treatment consisted of flocculating with alum, and filtration. The capacity of the treating plant was exceeded early in the life of the project and large quantities of untreated water were injected with no measurable harmful effect.

After preliminary injection tests on one of the injection wells, full-time injection was started February 8, 1944. It was found that about 2400 barrels of water a day could be injected at a pressure of 2500 pounds per square inch. It has apparently been possible to maintain injection rates without increasing pressure. A second injection well was put into operation about a year later.

In addition to providing a means of disposal of waste water, injection has increased oil production in an adjacent well. This increase was from a normal average of 150 barrels per day to more than 300 barrels per day. When the injection well was shut in for repairs at a later date, production in the adjacent well dropped back to 150 barrels per day, but the higher rate was regained when injection was resumed. An oil-producing well adjacent to the second injection well showed a similar increase in production.

Although this project also has been of too short duration to show any conclusive results, it does show that primary pressure control by water injection may be feasible.

Water Injection at Lost Hills

In 1946, a Standard Oil Company deep test well, located at the south end of the Lost Hills field, had reached a depth of 11,080 feet when the drill pipe was lost. Casing was set in the well above the drill pipe at 8853 feet. The interval through the lower Miocene was gun perforated and tested but was found to contain only salt water under high pressure. The source of this water was probably the Carneros sandstone. The presence of this high pressure water source led to a decision to inject water into an upper producing zone through an edge well. The water was produced at the surface under sufficient pressure to be injected directly through a closed system. Injection was commenced early in 1947.

---

[4] Crooker, J. T., and Schnoor, F. H., Waste water injection in the Stevens zone, Greeley field: Am. Petroleum Inst. Paper 801-22E, 1946.

A large amount of water has been injected into the well, but no benefit has been derived. This is believed to be a result of the water invading a zone other than that anticipated. Water injection has been suspended at the present time.

Summary

Although little positive information can be obtained from the foregoing review, no adverse results were noted. In at least two cases, it has been found possible to inject water into California reservoir sands and, as a result, to increase oil production. It is interesting to note that conditions are considerably different in the two fields in that one field has an active edgewater drive whereas in the other field it is very limited. There is no indication from the results so far obtained as to how efficient water is in displacing oil from these reservoirs, or as to whether the process would be economically feasible. However, because of the limited scale of the projects and the fact that they are experimental in nature, it might be deduced that the results will represent only the lower limit of success of such work.

Characteristics of California Oil Fields

A general summary of the characteristics of California oil fields is presented in tables 1 through 3. The 98 fields and areas summarized include all the fields in the state except a few of the newest fields and a few small unimportant areas. The fields are divided into the five districts as designated by the State Division of Oil and Gas. Because of the lack of detailed information and for purposes of simplification, many small fields have been grouped under one major heading, conforming to the designation adopted by the Division of Oil and Gas.

The data appearing in these tables were gathered from a great many sources and, as a result, the degree of accuracy and reliability is highly variable. In cases of conflicting information the most recent interpretation is generally recorded. Altogether too much of the desired information was completely lacking. This was particularly true of core-analysis information, where either no core data were available or insufficient information was available to give representative values. Regardless of these shortcomings, the tables fulfill their purpose as a preliminary survey and some general conclusions may be reached in their interpretation. It is sincerely hoped that information will be volunteered to correct, substantiate, and complete these tables so that they may serve many useful functions.

Acknowledgments are hereby made to all those who furnished data for these tables, and in particular to the following persons and publications: (1.) R. D. Bush, State Oil and Gas Supervisor, and Deputies, District offices, State of California, Division of Oil and Gas; (2.) Railroad Commission of the State of California and the California Division of Oil and Gas, Case No. 4591, Special Study No. S-525, *Estimate of the natural gas reserves of the State of California as of January 1, 1946,* June 1, 1946; (3.) State of California, Division of Oil and Gas, *Summary of operations of California oil fields,* vols. 10-34; (4.) State of California, Division of Mines, Bull. 118, *Geologic formations and economic development of the oil and gas fields of California,* April 1943; (5.) United States Bureau of Mines, Rept. Inv. 2489, *Analysis of crude* *oils from 283 important oil fields in the United States,* by C. M. McKinney and O. C. Blade, May 1948; (6.) American Institute of Mining and Metallurgical Engineers, Statistics of Oil and Gas Development and Production, *Petroleum development and production in California in 1947,* by William R. Wardner, pp. 27-43, 1948; (7.) Petroleum Administrator for War, *Preliminary secondary recovery report,* by C. L. Moore, 1942; (8.) Oil's 1947 Yearbook and Directory Number, vol. III, no. 40, Oct. 2, 1947; (9.) Producing Department, Standard Oil Company of California, San Francisco, California.

In the following discussion of the tables it should be remembered that in the final analysis each field must be considered individually in the light of its own characteristics, for certain adverse characteristics may be offset by other unusually favorable characteristics. However, a general analysis of the tables as a whole will serve to substantiate general statements made in Part 1 of this paper.

Table 1, Physical Characteristics of California Oil Fields

Table 1 (p. 371) is a survey of the physical characteristics of each field and each zone within the fields. It should be noted that in this and the other tables the data given opposite the field name apply to the field as a whole. In some cases these figures represent average or the only available values while in others they represent the total for the field as a whole.

The discovery date may indicate how near the field or zone is approaching the end of its primary period of production. This, however, must be coupled with production-decline data to yield a reliable index. It is interesting to note that more than half the zones in California fields have had a productive life of 20 years or more. In many fields it was difficult to estimate an average depth of producing zones because of the high dips of the beds. However, more than two-thirds of the producing zones in California are less than 5000 feet in depth, and nearly one-third of the zones are less than 2000 feet.

The difference between maximum and current productive acreage may be partly accounted for by edgewater encroachment. The productive acreage of each zone would have been of greater value to this work than the areal extent of the field as a whole; however, this information was not available in most cases. The number of potential wells include presently productive wells and idle wells which may still be capable of producing. The value of ''acres per well'' was obtained by dividing the current productive acreage by the number of potential wells in the field. This gives surface well density rather than the more desirable value of well spacing in each zone. Nevertheless, it would appear that exceptionally close well spacing has been employed in most of the older California fields.

A certain amount of controversy seems to exist as to the correct values of zone thicknesses. This is occasioned in part by the different methods of expressing thicknesses, some giving total zone thickness and percent productive sand, while others give net thickness of sand. It is, of course, important that the proper value be known in calculating acre-feet of sand for reserve studies. The data presented in the table substantiate earlier statements to the effect that California producing zones are exceptionally thick in comparison with those of most other oil-producing regions.

Reliable porosity and permeability data on California reservoir sands are scarce. The values given in the tables can not be used in engineering calculations with any degree of assurance; they serve only to give the relative magnitude of these properties. Porosities are generally moderate to high, averaging about 25 percent. Permeability to air, expressed in millidarcys, is generally low but is exceedingly variable.

Table 2, Geological and Mineralogical Characteristics of California Oil Fields

The geologic formations in which the oil-producing zones occur and the ages of the formations are given in table 2 (p. 386), on the assumption that each formation may have certain common characteristics which may be correlated from field to field. Because of the erratic conditions of sedimentation characteristic to California formations, such correlation is difficult and will serve only as a general guide where specific information is lacking. This assumption has been employed in a few instances in deducing mineralogical characteristics.

The great majority of California oil accumulations are in structural traps. Anticlines and domes are the most common primary structures; faults, unconformities, and lateral changes in sand characteristics are important as secondary controls. Many of the structures are irregular and asymmetric with moderate to steep dipping beds. Most of the fields in District I are on folds along the axes of major faults. The structures are, for the most part, anticlines and monoclines with closures effected by faults. Although structures in District I are more regular than in other districts they are intersected and displaced by numerous faults. The fields in District II are similar to those in District I except that most of the structures are local irregularities on major anticlinal folds and beds are, in general, more steeply dipping. Structures in District III are among the most complex in California. Monoclinal structures predominate; closures are effected by faults, unconformities, bituminous seals, and changes in sand characteristics. Dips of formations range from low to high. District IV can be most conveniently divided into three parts for purposes of this discussion. In the eastern fields, oil accumulation is caused mostly by faults, and monoclines controlled by unconformities. In the central fields there are deep-seated domes and anticlines, and faulting and lithologic changes are of secondary importance. The westside fields, including District V, are more diversified in structure. Structures in the older sediments are for the most part domes and anticlines. Minor faulting and thinning of beds modify these structures. The younger sediments were laid down unconformably over the older beds and many of the accumulations occur in sands buttressed against the old relief. In Districts IV and V the formations generally dip at low angles.

Structural conditions in California oil fields will present definite problems in attempts to water-flood. Gravity segregation in the comparatively steeply dipping formations may limit the application of blanket flooding. Considerable subsurface information will be required to delineate fault blocks, so common to California fields, and to permit selective flooding of isolated blocks.

Little is known of the mineralogy of California reservoirs. For the most part, however, they consist of poorly sorted, poorly to firmly consolidated, arkosic sands containing appreciable quantities of clay and silt. This is generally true of Pleistocene and Pliocene sediments and to a lesser degree of Miocene formations. In some areas, Miocene sediments may be more correctly classed as graywackes. The few well-sorted, well-consolidated, clean sands in California are of Eocene age.

In table 2 the continuity, or lack thereof, of California reservoir sands has been depicted. Most productive formations consist of interbedded sands, silts, and clays or shales. Many of the sands are discontinuous or lenticular.

It is difficult to judge the effect that mineralogical characteristics of reservoir sands will have on water-flooding. To prevent swelling of clays in the reservoir sands, special consideration in the selection of injection water will be required. In addition, the lack of continuity of the sands, both vertically and horizontally, will complicate injection and control of flood water.

Table 3, Water and Oil Characteristics and Production from California Oil Fields

Limited information is available regarding the interstitial water content of California reservoir sands. Most of the values presented in table 3 (p. 401) were deduced from relations between permeability and water content of similar sands. Because of the low permeability of many California sands, high interstitial water content would be expected. Data on the salinity of produced waters were likewise not available in most cases. The predominating constituents of the water have been noted in a few instances. The change in the total percent water production for each field during the 5-year period gives an indication of water conditions in the field. It is not safe to assume that an increase in water production during the period necessarily indicates an effective edgewater drive; nor is it safe to assume that because there is no change or a decrease in water production, the edgewater drive is ineffective. Condition of casing and water shutoffs, the presence of bottom and intermediate waters, and well repairs and abandonments must all be considered in analyzing these figures. Few California fields are known to have effective edgewater drives, yet it is surprising to note the relatively high percentage of water production in many fields. This is undoubtedly attributable in part to the presence of wet sands within the productive intervals and to the influx of bottom waters. Another cause might be the high relative permeability of the sands to water due to the supposedly high interstitial water saturation. This high relative permeability to water would permit easy passage of edgewater through the producing zones.

The average oil production per well per day in most California fields has remained comparatively high throughout the years. This has been influenced strongly by the discovery of new flush zones within the fields tending to maintain high averages. Of the 98 fields and groups covered in the survey, only 36 produce at an average rate of less than 25 barrels per well per day, and only 12 fields average less than 10 barrels per well per day. If consideration were given, however, to the production rates from individual zones within many of the older fields, a considerable proportion would be found to be near the end of their primary production period.

The properties of the crude oil produced from each field and zone complete the tabulation of table 3. The gravities of California crude oil range from 8° to more than 50° A.P.I., but the average is low in comparison to most other oil-producing regions. This low gravity generally indicates unfavorable properties, although the selling price is high. The viscosities given in the table were measured at 100° F. and would be lower under reservoir conditions. Nevertheless, the viscosity of California crude oil is higher than that for oils which have been successfully recovered by water-flooding in other regions.

Table 1. Physical characteristics of California oil fields

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre-ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
	District I															
1	ALISO CANYON			730	730	37	52	14.0								1
	Porter	1938	5000						450	50	20,500		26		485	
	Sesnon	1938	8000						200	60			23		200	
2	ALONDRA			50	50	5	5	10.0	60N[2]							2
	Monterey	1946	9100													
3	BEVERLY HILLS			15	120	2	2	7.5	400							3
	Plio.-Mio. Trans.	1909	2450													
4	BREA-OLINDA			1538	1688	392	543	2.8	800N							4
	Repetto	1897	800										High			
	Puente	1899	1000													
5	CHINO AREA			10	20	1	1	10.0	100N							5
	Puente	1931	2600													
6	COYOTE, E.			1180	1405	205	226	5.2								6
	Hualde		2500						200	50						
	Anaheim	1911	3300						550	50						
	2nd		3800						300	50						
	3rd	1931	5300						300	30						
	Stern	1929	6900						850	60						
7	COYOTE, W.			983	1030	238	262	3.8					20			7
	Top	1909	2800						200	50						
	Main	1909	3200						900	60						
	"99"	1924	4300						450	60					410	
	Emery	1930	5900						1000	40	223,000		22.2		150	
	McNally	1939	7000												Low	

Table 1. Physical characteristics of California oil fields—Continued

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre-ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
8	DEL VALLE			660	685	71	73	9.1								8
	Sepulveda	1942	5100						130	40			20		225	
	Vasquez	1945	5600						110	60	9,400	23-26	24	190-280	220	
	Videgain	1940	6000						200	60	21,000		23		190	
	Del Valle	1940	6900						200	50	19,800		24		220	
	Bering	1943	8000						385	30	17,700		19		130	
9	DOMINGUEZ			1205	1385	337	358	3.4								9
	1st	1923	4100						440	55			28.5		145	
	2nd	1927	4500						200	60			28.0		143	
	3rd	1924	4800						395	65			27.5		130	
	4th	1927	5000						250	70			26.5		113	
	5th	1931	5400						765	30			25.5		98	
	6th	1934	6500						395	20			24.0		40	
	7th	1935	7200						545	40			20.0		84	
	8th	1936	7600						870	15			20.0		95	
10	E. LOS ANGELES			150	150	8	8	18.7								10
	U. Miocene	1946	8600						70N				21			
11	EL SEGUNDO			340	773	27	34	10.0	50N							11
	Congl.	1935	7300										Low		Low	
	Schist		7000										25		Mod.	
12	HUNTINGTON BEACH			3405	3663	1057	1203	2.8								12
	(Old Field)															
	U. Bolsa	1920	2300						340N	45	7,500		28			
	L. Bolsa	1920	2600										28			
	U. Ashton	1921	3500						70N	45	39,500		26.5			
	L. Ashton	1922	3800						270N	45	134,000		25			
	(Offshore Field)															
	Tar	1926	2000						200	45			25			
	Jones	1926	3100						200	45			36.8		914	
	Main	1933	4500						700	45			28.6		902	
13	INGLEWOOD			895	925	317	336	2.7					29			13
	Vickers	1924	2200						1100	50						
	Rindge	1925	3200						1000	40						
	Rubel	1934	3300						800	60						
	Moynier	1932	6500						300	20						
	Sentous	1940	8800						400	40	8,100		17			

14	LAWNDALE			50	58	5	7	7.1								14
	U. Miocene	1928	5900						200	30						
15	LONG BEACH			1158	1550	1112	1239	0.9					30			15
	U. Wilbur	1921	2600						800	25						
	L. Wilbur	1921	3100						300	50						
	Alamitos	1921	3700						700	50						
	Brown	1923	4800						1500	75						
	Deep	1926	6500						2800	70						
	De Soto	1938	10000						400	70						
16	LOS ANGELES CITY			250	780	87	88	2.8								16
	U. Puente	1892	900						200							
17	MONTEBELLO			1323	1548	325	367	3.6								17
	1st	1917	2400						700	60						
	2nd	1917	3200						600	80						
	3rd	1920	3700						300	50						
	4th	1930	5000													
	(West)															
	5th	1938	5500						300				27		400	
	6th	1937	6200						350				27		250	
	7th	1938	7000						400				23.5		125	
	8-1	1939	7200						100				20		80	
	8-2	1939	7300						100				22		100	
18	NEWHALL GROUP			430	675	19	92	4.7								18
	(Elsmere Canyon)	1889	900						150							
	Pico															
	Eocene															
	(Pico Canyon)	1875														
	Top		500						100							
	Central		2000						600	25						
	Lower		2200						400							
	(Towsley Canyon)															
	Modelo	1900	900													
	(Tunnel Area)															
	Pico	1889	1400						300							
	(Whitney Canyon)	1893	1500													
	Saugus															
	Pico								150							
	Eocene															
	(Wiley Canyon)															
	Modelo	1883	1500						300							

Table 1. Physical characteristics of California oil fields—Continued

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre-ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
19	NEWHALL-POTRERO			745	745	56	72	10.0	300N							19
	1st	1936	6500						350				17		165	
	2nd	1936	6800						120				14		105	
	3rd	1936	7100						300				17		65	
20	NEWPORT, W.			825	828	175	188	4.4								20
	"A"	1943	2200						350	70		29-37		570-1400		
	"B"	1945	2700						350	75		30-33	32	1000-3000	1284	
	"C"	1945	5000						300	5						
	Lyddon	1946	5500						50	75			30		750	
21	OAK CANYON			270	270	19	20	13.5					22			21
	Wickman	1941	2400						75	60						
	Gilmour	1944	5300						300							
	Max.-Weaver	1945	6500						300							
	Lechler	1941	7100						300	40			23		120	
22	PLAYA DEL REY			475	580	119	153	3.1	200N							22
	Upper	1930	4500						1100	15						
	Schist Congl.	1929	6600						75							
23	POTRERO	1927		195	235	27	32	6.1								23
	Pico		3500						125	60		23-35	29	200-700		
	U. Repetto		5000						500	50		To-18		To-40		
	M. Repetto		6300						400	50		To-18				
24	RICHFIELD			1245	1503	328	344	3.6								24
	Chapman	1918	3200						400	60		20-35	31	100-1300	1100	
	Kraemer	1920	4000						750	60			25			
	(Kraemer Area)															
	Kraemer	1918	2800													
25	ROSECRANS			765	890	183	217	3.5					22			25
	(Athens Area)															
	U. Athens	1925	4300						300							
	L. Athens	1924	4600						100							

	U. Howard Park	1924	4800						100	60						
	L. Howard Park	1924	5000						300	80						
	L. Zins	1927	7200						300	80						
	O'Dea	1940	7700						200	70						
	(Main Street)															
	Padelford	1924	4100						200	75						
	U. Maxwell	1924	4400						400	60						
	L. Maxwell	1924	4700						300	60						
	Hodge	1924	5000						650	60						
	Zins	1927	6000						800	50						
	O'Dea	1937	7400						400	50						
26	SALT LAKE			15	905	5	5	3.0								26
	Repetto	1903	1950						1000	40						
27	SANTA FE SPRINGS			1010	1410	544	607	1.7								27
	Foix	1922	3500						100	80						
	Bell	1921	3700						300	80			29		945	
	Meyer	1919	4500						650	70						
	Nordstrom	1928	5400						500	70						
	Buckbee	1928	5800						450	60						
	O'Connell	1929	6600						450	60						
	Clark-Hath	1929	7900						1200	60						
28	SEAL BEACH			605	675	186	204	3.0					25			28
	Bixby	1926	4400						170	80						
	Selover	1926	4700						250	70						
	Wasem	1927	5600						1000	70						
	McGrath	1928	6600						1500	80						
29	TORRANCE			4775	5753	738	829	5.8					27			29
	Main	1922	3500						600	15						
	Harbor City	1936	4750						200	10						
	Del Amo	1936	5000						200	60						
30	TURNBULL			65	75	5	5	13.0								30
		1941	3400						190N				27			
31	WHITTIER			620	708	159	196	3.2								31
	1st	1898	2200						500	50						
	2nd	1898	2600						100	80						
	3rd	1897	3200						400	50						
	4th		4200						500	50						
	L. Puente		5000						1500							

Table 1. *Physical characteristics of California oil fields—Continued*

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
32	WILMINGTON			5455	5460	1936	1986	2.7								32
	Tar	1935	2300						300	40			32		500	
	Ranger	1937	2600						500	25			31		450	
	U. Terminal	1937	3200						400	65			32		450	
	L. Terminal	1936	3700						700	50			32		450	
	Ford	1936	5000						750	30			24		75	
	"237"	1946	5600						300	25			25		1000	
	District II															
33	BARDSDALE AREA			1090	1110	192	238	4.6								33
	(Bardsdale)					(58)			1000							
	Sespe	1891	1400											25-600		
	Eocene	1936	6400													
	(Shiells Canyon)															
	Top	1911	600			(149)			500							
	Intermediate	1911	2200						300							
	Deep	1934	3800						1000	30						
	(Torrey Canyon)															
	Sespe	1896	1400						250							
34	MONTALVO, W.			60	60	2	2	30.0								34
	Repetto	1947	8500													
35	OJAI GROUP			570	735	59	101	5.6								35
	(Sulphur Mt.)	1927	2500													
	(Sissar Creek)	1890	1000													
	(Sissar Silverthread)	1885	700													
	(U. Ojai Valley)	1890	1000													
36	OXNARD	1937		230	230	7	11	20.9	200N							36
	Vaca tar		2200													
	Brown shale		3500													
	Frac. Volc.		4000													

37	PIRU AREA			760	985	140	181	4.2							37
	(Hopper Canyon)	1887	1800						700	60					
	(Modelo)	1898	2000						450	10					
	(Temescal)	1924	2500						650	10					
38	RINCON AREA			1475	1475	205	217	6.8							38
	(Padre Canyon)	1936	5600			(51)			1200	60					
	(Rincon)	1927				(100)									
	Top		3500						75	35					
	Intermediate		3800						300	35					
	Miley		4500						800	35					
	(San Miguelito)	1931	6700			(54)			1600	45			18		
39	SANTA PAULA GROUP			150	445	30	44	3.4							39
	(Adams Canyon)	1900	900												
	(Ex-Mission)	1875	850												
	(Salt Marsh)	1900	900												
	(Timber Canyon)	1885	1500												
	(Wheeler Canyon)	1900	950												
40	SESPE CANYON GROUP			230	625	27	36	6.4							40
	(Sespe Forks)	1890	900						1000?						
	Sespe														
	U. Tejon														
	(Topatopa)	1889	1200						500?						
	L. Vaqueros														
	U. Sespe														
41	SIMI			570	625	57	73	7.8							41
	L. Sespe	1912	800						100						
	Llajas	1912	1650						100						
42	SOUTH MOUNTAIN			1295	1300	165	176	7.4							42
	L. Sespe	1916	3400						4000	25		14-20		35-350	
	(West Mountain)														
	Sespe	1945	5000			(24)			1500	25			Low		Low
43	VENTURA AVENUE			2590	2590	594	682	3.8							43
	"A"	1916	5200						800	25	584,000		21		
	"B"		6900						2000	25	1,016,000		20		
	"C"	1926	8900						1500	25	772,000		17.5		

Table 1. Physical characteristics of California oil fields—Continued

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre-ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
	District III															
44	Arroyo Grande			300	600	20	39	7.7	100N				30		High	44
	U. Santa Margarita	1906	1200													
	L. Santa Margarita	1906	2500													
45	Capitan			230	370	64	76	3.0	135N							45
	Vaqueros	1929	1400						350				22			
	2d Ft. Sand	1931	2200						20				19			
	1st Erburu	1931	2300						125				19			
	2nd Erburu	1931	2600						75				19			
	3rd Erburu	1931	2800						150				19			
46	Casmallia	1917		1020	1940	27	68	15.0								46
	Shale		1600						750							
	Chert		2200													
47	Cat Canyon			3060	3110	190	236	13.0								47
	(East)	1909	3400						450							
	(West)	1908	3200						500							
	(Gato Ridge)	1931														
	L. Sisquoc		2000													
	Monterey		2500						2000							
48	Elwood			690	690	74	104	6.6								48
	Vaqueros	1928	3200						300				24		High	
	Sespe	1931	3900						100							
49	Four Deer					8										49
	Miocene	1947	4900													
50	Lompoc			1960	3060	82	92	21.3								50
	U. Monterey	1903	2700						500							
51	Mesa			22	102	16	17	1.3								51
	Vaqueros	1929	2200						40N				34		High	

52	MOODY GULCH	-----	-----	10	40	1	1	10.0	-----	-----	-----	-----	-----	-----	-----	52
	San Lorenzo	1880	1100	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
53	SANTA MARIA	1902	-----	3550	4900	231	301	11.8	-----	-----	-----	-----	-----	-----	-----	53
	Sisquoc	-----	2100	-----	-----	-----	-----	-----	200	-----	-----	-----	-----	-----	-----	
	Santa Margarita	-----	2600	-----	-----	-----	-----	-----	300	-----	-----	-----	-----	-----	-----	
	L. Monterey	-----	3200	-----	-----	-----	-----	-----	500	-----	-----	-----	-----	-----	-----	
54	SANTA MARIA VALLEY	1936	-----	6280	6280	478	508	12.4	-----	-----	-----	-----	-----	-----	-----	54
	Santa Margarita	-----	3900	-----	-----	-----	-----	-----	200	-----	-----	-----	-----	-----	-----	
	Monterey Chert	-----	4300	-----	-----	-----	-----	-----	500	-----	-----	-----	-----	-----	-----	
	Monterey Sand	-----	4600	-----	-----	-----	-----	-----	400	-----	-----	-----	-----	-----	-----	
55	SARGENT	-----	-----	80	80	0	9	8.9	300N?	-----	-----	-----	-----	-----	-----	55
	Pliocene	1904	1200	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
56	SUMMERLAND	-----	-----	20	55	2	12	1.7	10-100	-----	-----	-----	-----	-----	-----	56
	Basal Pliocene	1890	800	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
	Vaqueros	1907	1350	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	
57	ZACA CREEK	-----	-----	200	200	6	6	33.3	-----	-----	-----	-----	-----	-----	-----	57
	U. Miocene	1942	5500	-----	-----	-----	-----	-----	400N	-----	-----	-----	-----	-----	-----	
	District IV															
58	ANTELOPE HILLS	-----	-----	245	245	27	30	8.2	85N	-----	-----	-----	-----	-----	-----	58
	"67-6"	1942	1900	-----	-----	-----	-----	-----	380	10	-----	23-40	-----	0-1000	-----	
	"23-6"	-----	2100	-----	-----	-----	-----	-----	160	-----	24,500	14-39	30	1-1100	-----	
	"45-6"	1942	2300	-----	-----	-----	-----	-----	300	-----	-----	18-32.5	-----	3-2090	-----	
59	ANT HILL	-----	-----	295	305	32	35	8.4	45N	-----	-----	-----	-----	-----	-----	59
	Olcese	1944	2200	-----	-----	-----	-----	-----	100	-----	-----	-----	-----	-----	-----	
	Jewett	1944	3600	-----	-----	-----	-----	-----	150	25	-----	-----	-----	-----	-----	
60	BELRIDGE, N.	-----	-----	1875	1915	76	141	13.3	625N	-----	-----	-----	-----	-----	-----	60
	Maricopa Shale	1912	2400	-----	-----	-----	-----	-----	200	-----	-----	-----	-----	-----	-----	
	Temblor	1930	5400	-----	-----	-----	-----	-----	500	50	-----	-----	20	-----	-----	
	"R" Sand	1942	7800	-----	-----	-----	-----	-----	275	60	172,400	-----	12	-----	-----	
	Bloemer	1932	8000	-----	-----	-----	-----	-----	85	90	76,600	-----	14	-----	-----	
	Belridge	1932	8200	-----	-----	-----	-----	-----	400	90	326,600	-----	14	-----	-----	
	"Y" Sand	1942	8500	-----	-----	-----	-----	-----	30	60	32,500	-----	11.5	-----	-----	

Table 1. Physical characteristics of California oil fields—Continued

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre-ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
61	BELRIDGE, S.			6000	6155	561	971	6.2	50N							61
	Tulare	1942	700						200				39	500-5000		
	Maricopa Shale	1911	900													
62	BLACKWELL'S CORNER			190	200	27	28	6.8								62
	Vaqueros	1941	1000						90N							
63	CANAL			780	780	32	39	20.0								63
	Stevens	1937	8300						400	50	120,000	15-30	22	60-800	200	
64	COLES LEVEE, N.			3230	3230	95	117	27.6								64
	"22-1"	1938	8400						50N				21.5		126	
	U. Western		8600						110N				19.0		72	
	L. Western		9000						210N				19.5		109	
65	COLES LEVEE, S.			3200	3200	63	71	45.0	300N				20			65
	"F-1"	1938	8800													
	U. Western		9000													
	L. Western		9400						120N				18		58	
66	CYMRIC GROUP			2425	2485	360	407	6.0								66
	(McKittrick Front)								350N							
	Amnicola		1400						500							
	Franco-Western	1917	2400						100							
	(Salt Creek)								30N				32	1000-3000		
	Amnicola	1946														
	Carneros	1946	2800						200							
	(Sheep Springs)								21N							
	Carneros	1944	3500						30							
	Oceanic	1947	4850						30				26		700	
	(Welport)								145N			20-28				
	Amnicola	1916	1550						50							
	Fitzgerald		3500						70							
	Anderson	1945	3600						50							
	Weston	1945	3600						100							

	Weston-3	1945	3500						50							
	Phacoides	1945	4000						125							
	Oceanic	1945	4700						160				26		700	
	Point of Rocks	1946	5300						80						Low	
67	Devil's Den			140	250	7	32	4.4								67
	Wagon Wheel	1910	2000						200							
68	Edison			2815	2910	302	317	8.9	125N							68
	U. Duff	1934	1800						200	30						
	L. Duff	1934	3300						100							
	Schist	1935	3500						100							
69	Elk Hills			15790	15910	149	684	23.1				20-38				69
	Scalez	1919	3000						65N				35		1500	
	Mulinia	1920	3200						35N				34		1500	
	Stevens	1940	7000						100N				26.5			
70	Fruitvale			2030	2245	187	229	8.9								70
	Etchegoin	1928	3200						50N						High	
	Chanac		3600						300	30			Low		Low	
71	Greeley			1960	2060	94	102	19.2								71
	Stevens	1936	7800						100	65			21			
	Vedder	1938	11500						250	50			21	To-4000	423	
72	Kern Bluff			205	205	18	18	11.4								72
	Santa Margarita	1947	800													
73	Kern Front			4205	4220	657	686	6.1	80N				35			73
	Etchegoin	1915	1500						50							
	Chanac	1915	2400						400	10-50						
74	Kern River			7815	7855	2477	2704	2.9	130N				35			74
	Kern River	1899	800						400							
75	Lost Hills			3080	3250	557	602	5.1								75
	Etchegoin Upper	1910	400						200	60						
	Etchegoin Lower	1910	1500						300	60						
	(Williamson Area)															
	Amnicola	1936	200													
	2nd	1936	1200						100							
	3rd	1936	1600						100							
	4th	1936	1800						50							

Table 1. *Physical characteristics of California oil fields—Continued*

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre-ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
76	McDONALD ANTICLINE	1945	900	85	85	11	12	7.1	105N							76
	Phacoides															
	Oceanic															
77	McKITTRICK			1300	1430	248	298	4.4								77
	Amnicola	1900	1000						75							
	Olig	1900	1400						300				38			
78	MIDWAY-SUNSET GROUP			43000	47520	3811	4447	9.7								78
	(Buena Vista Front)															
	Scalez		4000						40N				25			
	(Buena Vista Hills)															
	Mulinia	1909	2500						150				27.4		213	
	27B	1944	4400						40N		155,700	21-30	26		230	
	(Gibson Area)															
	Scalez		2400						100N							
	Gibson	1937	2800						75N							
	(North Midway)	1901														
	Tulare		1000													
	San Joaquin		1600													
	Etchegoin		2000													
	Reef Ridge		2400													
	(Republic Area)															
	Tulare	1911	900						50							
	Etchegoin	1911	1500						100							
	Republic	1928	2800						250							
	(Santiago)															
	Leutholtz	1945	2500						500							
	(Twenty-five Hills)	1901														
	A Zone		1000						300							
	B Zone		2000						300							
	(Williams Area)															
	U. Williams	1929	1500						250N							
	M. Williams	1936	1700						150N							
	L. Williams	1936	1900						100N							
79	MOUNT POSO GROUP			3035	3140	526	544	5.6	150N				35			79
	U. Vedder	1926	1700						75							
	L. Vedder	1923	1800						190							

80	MOUNTAIN VIEW			1880	2585	151	200	9.4	70N							80
	Nichols	1934	5200						40							
	Clendenen	1933	5500						200							
	Warton	1933	5900						60							
81	PALOMA			6000	6010	90	110	5.5								81
	U. Stevens	1939	10300						200N		1,060,000		20	To-500	75	
82	POSO CREEK GROUP	1929	2800	1960	1970	226	243	8.1								82
	Etchegoin								20							
	Chanac								250	40						
83	RIO BRAVO			1870	1890	91	101	18.5								83
	Rio Bravo	1937	11300						300	50	318,000		22	100-3000	450	
	Vedder	1938	11500													
84	ROUND MT. GROUP			2355	2385	354	361	6.5					34			84
	Jewett	1928	1800						450	30					Low	
	Elbe	1928	1950						150	30						
	Vedder	1927	2200						100	50						
85	STRAND			380	380	22	24	15.8								85
	(West)	1939														
	Canal		8300						80	40	6,900		23			
	1st Stevens		8400						170	25	10,400		24			
	2nd Stevens		8700						250	12	8,000		24			
	3rd Stevens		9000						400	5	3,500		23			
	(East)															
	1st Stevens	1943	8300						55N		12,100		24.2		100	
86	TEJON			990	990	81	85	11.6								86
	Chanac-Santa Marg.	1943	2650						300	15						
	Reserve	1935	4000						30N							
87	TEN SECTION			1880	1910	112	124	15.2								87
	Stevens	1936	8200						400	40	372,000		20.4	100-400	140	
88	WASCO			150	260	4	6	25.0								88
	A-2	1938	13100						45N		14,000	11-24	18	130-3000	232	

Table 1. Physical characteristics of California oil fields—Continued

No.	Field and zone	Disc. date	Av. depth	Proven acres		No. wells		Acres per well[1]	Zone thick	Percent prod. sand	Acre-ft.	Porosity		Permeability		No.
				7-1-48	Max.	Prod.	Pot.					Range	Av.	Range	Av.	
89	WHEELER RIDGE			270	330	35	35	7.7	600N				28			89
	Tulare	1948	1200													
	Etchegoin	1923	2600						500							
	Santa Margarita	1923	4000						800							
	District V															
90	COALINGA GROUP			16180	17135	1504	1762	9.2								90
	(East)								17N							
	Temblor	1900	2100						600			21-30	26.9		683	
	(West)	1901							180N							
	"A"		1800						100			20-46	32.2	To-4500	259	
	"B"		2100						200							
	"D"		2400						200							
	(Oil City)															
	Moreno	1898	1200						200	25						
91	COALINGA EXTENSION			4320	4490	188	231	18.7								91
	(North East)															
	Gatchell	1939	8000						130N				23			
	(Nose)															
	Gatchell	1938	7000						360N				20	To-3800	600	
92	HELM			4230	4525	82	106	39.9								92
	Zilch	1941	7500						20N				25			
	Eocene	1941	7900						20N				35			
	Weyant	1942	8000						10N							
93	JACALITOS	1941	3900	1460	1560	83	85	17.2	45N		100,000		23	15-530	175	93
	U. Temblor															
	L. Temblor															

94	KETTLEMAN N. DOME			13075	13390	314	428	30.5								94
	Temblor 1								48N		2,827,000		14			
	Temblor 2								55N				15			
	Temblor 3	1928	8000						73N				17.5			
	Temblor 4								47N				12.5			
	Temblor 5								107N				14			
	Vaqueros	1933	8700						45N			16.5-22.3	19.3		80	
	McAdams A	1937	10800						150N		1,594,000		16		75	
	McAdams B	1937							45N		174,000		15		75	
95	PLEASANT VALLEY			480	480	22	26	18.5								95
	L. Gatchell	1943	9100						200N				14		75	
96	PYRAMID HILLS			145	145	24	25	5.8								96
	Kreyenhagen	1931	700						30N							
97	RAISIN CITY			935	1035	38	41	22.8								97
	Miocene	1941	5100						17N		13,500		22			
	Surfluh	1942	6300						7N		1,100		19			
	Eocene Main	1942	6400						7N		5,500		25			
	Eocene White	1942							9N		1,600		25			
98	RIVERDALE			1310	1630	49	62	21.1								98
	"66"	1941	6600						19N		32,000		25			
	"68"	1941	6800						15N		27,000		25			
	Courtney	1942	8000						9N		16,000		30			

---

[1] Current proven acreage divided by number of potential wells.

[2] Net sand thickness.

Table 2. Geological and mineralogical characteristics of California oil fields

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sorting	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
	District I												
1	ALISO CANYON			Monocl.									1
	Porter	Pico	U.P.		Lith.	20-40	S	F-M			Silt.	Lentic.	
	Sesnon	Monterey	U.M.		Fault.	30	S						
2	ALONDRA			Anticl.	Fault.								2
	Monterey	Monterey	U.M.				S, Cg.						
3	BEVERLY HILLS			Dome		15-45							3
	Plio-Mio. Trans.	Plio.-Mio. Trans	L.P.				S						
4	BREA-OLINDA			Anticl.	Fault.	25-40							4
	Repetto	Repetto	L.P.				S	C			Clay	Interb. Sh.	
	Puente	Puente	U.M.				S						
5	CHINO AREA			Fault	Anticl.								5
	Puente	Puente	U.M.				S						
6	COYOTE, E.			Domes	Fault.	To-57							6
	Hualde	Repetto	L.P.				S						
	Anaheim	Repetto	L.P.				S				Silt.	Interb. Sh.	
	2nd	Repetto	L.P.				S					Lentic.	
	3rd	Repetto	L.P.				S					Lentic.	
	Stern	Puente	U.M.				S		Poor				
7	COYOTE, W.			Dome	Fault.	Mod.							7
	Top	Repetto	L.P.				S						
	Main	Repetto	L.P.				S						
	"99"	Repetto	L.P.				S						
	Emery	Repetto	L.P.				S						
	McNally	Puente?	U.M.?				S						

8	DEL VALLE			Anticl.	Lith.	Mod.							8
	Sepulveda	Pico	U.P.				S	F-C	Poor			Lentic.	
	Vasquez	Modelo	U.M.				S	F-C	Poor			Lentic.	
	Videgain	Modelo	U.M.				S	M-C	Poor			Lentic.	
	Del Valle	Modelo	U.M.				S	M-C	Poor			Lentic.	
	Bering	Modelo	U.M.				S	F-C	Poor				
9	DOMINGUEZ			Anticl.	Fault.	15-20							9
	1st	Repetto	L.P.				S	F-M	Fair	Fair	Clay	Interb. Sh.	
	2nd	Repetto	L.P.				S	F-M	Fair	Fair	Clay	Interb. Sh.	
	3rd	Repetto	L.P.				S	F-M	Fair	Fair	Clay	Interb. Sh.	
	4th	Repetto	L.P.				S	F-M	Fair	Fair	Caly	Interb. Sh.	
	5th	Repetto	L.P.				S	F-M	Fair	Fair	Clay	Interb. Sh.	
	6th	Puente	U.M.				S	F-M	Fair	Firm	Clay	Interb. Sh.	
	7th	Puente	U.M.				S	F-M	Fair	Firm	Clay	Interb. Sh.	
	8th	Puente	U.M.				S	F-M	Fair	Firm	Clay	Interb. Sh.	
10	E. LOS ANGELES			Anticl.	Lentic.-Fault								10
	U. Miocene	Puente	U.M.				S						
11	EL SEGUNDO			Anticl.	Uncon.	10							11
	Congl.	Puente	U.M.				Sch. Cg.						
	Schist	Franciscan	U.J.				F. Sch.						
12	HUNTINGTON BEACH												12
	(Old Field)			Monocl.	Fault.	Low							
	U. Bolsa	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	L. Bolsa	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	U. Ashton	Repetto	L.P.				S	F-C	Poor				
	L. Ashton	Puente	U.M.				S	F-C	Poor				
	(Offshore Field)			Anticl.	Fault.	10-40							
	Tar	Repetto	L.P.				S	F		Poor	Silt		
	Jones	Repetto	L.P.				S	F-C				Interb. Sh.	
	Main	Puente	U.M.				S	F-C				Interb. Sh.	
13	INGLEWOOD			Dome	Fault.	To-30							13
	Vickers	Pico	U.P.				S	F-C	Poor		Clay	Interb. Sh.	
	Rindge	Repetto	L.P.				S				Clay	Interb. Sh.	
	Rubel	Repetto	L.P.				S				Clay	Interb. Sh.	
	Moynier	Puente	U.M.				S				Clay	Interb. Sh.	
	Sentous	Monterey	U.M.				S	F-M			Clay	Interb. Sh.	
14	LAWNDALE			Anticl.	Fault.	Mod.							14
	U. Miocene	Puente	U.M.				S	F-M	Fair			Interb. Sh.	

Table 2. Geological and mineralogical characteristics of California oil fields—Continued

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sorting	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
15	LONG BEACH			Anticl.	Fault.	10-45							15
	U. Wilbur	Pico	U.P.				S	M-C		Uncon.		Lentic. and Interb. Sh.	
	L. Wilbur	Repetto	L.P.				S			Uncon.		Lentic. and Interb. Sh.	
	Alamitos	Repetto	L.P.				S	M-C		Fair	Clay	Lentic. and Interb. Sh.	
	Brown	Repetto	L.P.				S	F-C	Poor	Well	Clay	Lentic. and Interb. Sh.	
	Deep	Puente	U.M.				S	F		Well		Lentic. and Interb. Sh.	
	De Soto	Puente	U.M.				S	F-M		Well		Lentic. and Interb Sh.	
16	LOS ANGELES CITY			Anticl.	Complex-Fld.	High							16
	U. Puente	Puente	U.M.				S						
17	MONTEBELLO			Anticl.	Fault.-Lith.	Mod.							17
	1st	Repetto	L.P.				S	M-C	Poor			Lentic.	
	2nd	Repetto	L.P.				S	M-C	Poor			Lentic.	
	3rd	Repetto	L.P.				S	M-C	Poor			Lentic.	
	4th	Repetto	L.P.				S	M-C	Poor			Lentic.	
	(West)			Dome		5-12							
	5th	Repetto	L.P.				S	F-M	Fair		Clay	Lentic. and Interb. Sh.	
	6th	Puente	U.M.				S	F-M	Fair		Clay	Lentic. and Interb. Sh.	
	7th	Puente	U.M.				S	F-M	Fair		Clay	Lentic. and Interb. Sh.	
	8-1	Puente	U.M.				S	F-M	Fair		Clay	Lentic. and Interb. Sh.	
	8-2	Puente	U.M.				S	F-M	Fair		Clay	Lentic. and Interb. Sh.	
18	NEWHALL GROUP												18
	(Elsmere Canyon)			Monocl.	Fault.	12-24							
	Pico	Pico	U.P.				S						
	Eocene		M.E.				S						
	(Pico Canyon)			Anticl.		50-75							
	Top	Modelo	U.M.				F. Sh.					Lentic.	
	Central	Modelo	U.M.				S					Lentic.	
	Lower	Modelo	U.M.				S						
	(Towsley Canyon)			Anticl.		55-70							
	Modelo	Modelo	U.M.				S						
	(Tunnel Area)			Monocl.	Fault.	29							
	Pico	Pico	U.P.				S						
	(Whitney Canyon)			Monocl.	Fault.	15							
	Saugus	Saugus	L.Pl.				C.S. and CG.						
	Pico	Pico	U.P.				S						
	Eocene		M.E.				S						
	(Wiley Canyon)			Anticl.		40-80							
	Modelo						S					Lentic.	

19	Newhall-Potrero			Anticl.	Fault.	45-70							19
	1st	Modelo	U.M.				S	F-C	Poor			Lentic.	
	2nd	Modelo	U.M.				S	F-C	Poor			Lentic.	
	3rd	Modelo	U.M.				S	F-C	Poor			Lentic.	
20	Newport, W.			Fault.	Anticl.	Mod.							20
	"A"	Puente	U.M.				S	F-C	Poor			Interb. Sh.	
	"B"	Puente	U.M.				S	M-C	Well			Interb. Sh.	
	"C"	Puente	U.M.				F. Sh.						
	Lyddon	Puente	U.M.				S	F-M	Well	Poor		Interb. Sh.	
21	Oak Canyon			Anticl.	Sec. Dome	Mod.							21
	Wickman	Modelo	U.M.				S	F-C			Silt	Lentic.	
	Gilmour	Modelo	U.M.				S	F-C					
	Max.-Weaver	Modelo	U.M.				S	F-C					
	Lechler	Modelo	U.M.				S	F-C					
22	Playa Del Rey			Anticl.									22
	Upper	Repetto	L.P.		Fault.	10	S				Clay	Interb. Sh.	
	Schist Congl.	Monterey	U.M.		Uncon.	10-20	Sch. Cg.						
23	Potrero			Dome-Fault		5-15							23
	Pico	Pico	U.P.				S	F		Uncon.		Interb. Sh.	
	U. Repetto	Repetto	L.P.				S	M		Well, Fri.			
	M. Repetto	Repetto	L.P.				S	F-M		Well, Fri.			
24	Richfield			Dome	Fault.	To-25							24
	Chapman	Puente	U.M.				S	M	Poor	Fri.	Clay	Lentic.	
	Kraemer	Puente	U.M.				S				Clay	Interb. Sh.	
	(Kraemer Area)			Dome	Fault.								
	Kraemer	Puente	U.M.				S				Clay	Interb. Sh.	
25	Rosecrans												25
	(Athens Area)			Dome									
	U. Athens	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	L. Athens	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	U. Howard Park	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	L. Howard Park	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	L. Zins	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	O'Dea	Puente	U.M.				S	F-M	Poor		Silt	Interb. Sh.	
	(Main Street)			Dome	Fault.								
	Padelford	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	U. Maxwell	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	L. Maxwell	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	

Table 2. Geological and mineralogical characteristics of California oil fields—Continued

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sorting	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
	ROSECRANS—Continued												
	Hodge	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	Zins	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	O'Dea	Puente	U.M.				S	F-M	Poor		Silt	Interb. Sh.	
26	SALT LAKE			Complex Fold		High							26
	Repetto	Repetto	L.P.				S					Interb. Sh.	
27	SANTA FE SPRINGS			Dome		Low							27
	Foix	Repetto	L.P.				S	F-C		Poor			
	Bell	Repetto	L.P.				S	F-C		Poor			
	Meyer	Repetto	L.P.				S	F-C		Poor		Interb. Sh.	
	Nordstrom	Repetto	L.P.				S	F-C		Poor		Interb. Sh.	
	Buckbee	Repetto	L.P.				S	F		Fair		Interb. Sh.	
	O'Connell	Repetto	L.P.				S	M		Firm		Interb. Sh.	
	Clark-Hath.	Puente	U.M.				S	F		Well	Clay	Interb. Sh.	
28	SEAL BEACH			2 Domes	Fault	Mod.							28
	Bixby	Repetto	L.P.				S	F					
	Selover	Repetto	L.P.				S	M-C					
	Wasem	Repetto	L.P.				S	M-C				Interb. Sh.	
	McGrath	Puente	U.M.				S	F-M		Well	Silt		
29	TORRANCE			Anticl.	Min. Fold	5-12							29
	Main	Puente	U.M.				S	F		Firm		Thin S. Lenses	
	Harbor City	Puente	U.M.				S	F		Firm		Thin S. Lenses	
	Del Amo	Puente	U.M.				S	F		Firm		Thin S. Lenses	
30	TURNBULL			Anticl.	Fault								30
	Puente	Puente	U.M.				S						
31	WHITTIER			Fault	Monocl.	30							31
	1st	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	2nd	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	3rd	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	4th	Repetto	L.P.				S	F-C	Poor			Interb. Sh.	
	L. Puente	Puente	U.M.				S	F-C	Poor			Interb. Sh.	

32	WILMINGTON			Fault	Anticl.	Low							32
	Tar	Repetto	L.P.				S	F		Uncon.		Interb. Sh.	
	Ranger	Repetto	L.P.				S	F		Uncon.		Interb. Sh.	
	U. Terminal	Puente	U.M.				S	F		Uncon.		Interb. Sh.	
	L. Terminal	Puente	U.M.				S	F-M		Poor		Interb. Sh.	
	Ford	Puente	U.M.				S	M-C		Firm	Clay	Interb. Sh.	
	"237"	Franciscan	U.J.				S. and Sch.Cg.	C					
	District II												
33	BARDSDALE AREA												33
	(Bardsdale)			Anticl.	Fault.								
	Sespe	Sespe	O.				C.S.	F-M	Poor	Well	Benton?	Lentic. and Interb. Sh.	
	Eocene	Tejon	U.E.				S	F-M	Poor	Well	Silt	Interb. Sh.	
	(Shiells Canyon)			Anticl.		High							
	Top	Sespe	O.				C.S.	F-M	Poor	Firm	Benton?	Lentic. and Interb. Sh.	
	Intermediate	Sespe	O.				C.S. and Cg.	F-C	Poor	Firm		Lentic. and Interb. Sh.	
	Deep	Sespe	O.				C.S.	F-C	Poor	Firm		Lentic. and Interb. Sh.	
	(Torrey Canyon)			Anticl.	Fault.								
	Sespe	Sespe	O.				C.S.	F-M	Poor	Firm	Benton?	Lentic. and Interb. Sh.	
34	MONTALVO. W.												34
	Repetto	Repetto	L.P.				S						
35	OJAI GROUP			Monocl.	Fault.-Bit. Seal	To-80							35
	(Sulphur Mt.)	Sespe	O.				S						
	(Sissar Creek)	Sespe	O.										
	(Sissar Silverthread)	Sespe	O.				S. and F. Sh.						
	(U. Ojai Valley)	Sespe	O.										
36	OXNARD			Monocl.	Uncon.								36
	Vaca Tar	Pico	U.P.			Low	S	V.F.			Silt		
	Brown Shale	Modelo?	U.M.			5-40	F. Sh.						
	Frac. Volc.		M.M.			5-40	F. Volc.						
37	PIRU AREA												37
	(Hopper Canyon)	Modelo	U.M.	Anticl.	Fault.		S	C.	Fair	Firm		Interb. Sh.	
	(Modelo)	Modelo	U.M.	Anticl.			S	C.	Fair	Firm		Interb. Sh.	
	(Temescal)	Modelo	U.M.	Anticl.			S	C.	Fair	Firm		Interb. Sh.	
38	RINCON AREA												38
	(Padre Canyon)	Santa Paula	M.P.	Anticl.	Fault.		S	F-C	Poor	Firm		Lentic.	
	(Rincon)			Anticl.	Fault.								
	Top	Santa Paula	M.P.				S	F-C	Poor	Firm		Lentic.	
	Intermediate	Santa Paula	M.P.				S	F-C	Poor	Firm		Lentic.	
	Miley	Santa Paula	M.P.				S	F-C	Poor	Firm		Lentic. and Interb. Sh.	
	(San Miguelito)	Santa Paula	M.P.	Anticl.	Fault.		S	F-M	Poor	Firm		Lentic.	

Table 2. Geological and mineralogical characteristics of California oil fields—Continued

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sort-ing	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
39	SANTA PAULA GROUP			Monocl.	Fault.-Bit. Seal	45-60	S. and F. Sh.						39
	(Adams Canyon)	Repetto	L.P.										
	(Ex-Mission)	Repetto	L.P.				S						
	(Salt Marsh)	Repetto	L.P.										
	(Timber Canyon)	Repetto	L.P.										
	(Wheeler Canyon)	Repetto	L.P.										
40	SESPE CANYON GROUP												40
	(Sespe Forks)			Complex Fold	Fault.								
	Sespe	Sespe	O.				C.S.					Interb. Sh.	
	U. Tejon	Tejon	U.E.				S						
	(Topa Topa)			Complex Fold	Fault.								
	L. Vaqueros	Vaqueros	L.M.				S					Interb. Sh.	
	U. Sespe	Sespe	O.				C.S.					Interb. Sh.	
41	SIMI			Anticl.	Fault.	35							41
	L. Sespe	Sespe	O.				C.S.	F-C	Poor	Poor		Interb. Sh.	
	Llajas	Llajas	M.E.				S	M-C	Fair	Poor		Lentic.	
42	SOUTH MOUNTAIN			Dome	Fault.	12-60							42
	L. Sespe	Sespe	O.				C.S.	F-C	Poor	Poor-Well		Lentic. and Interb. Sh.	
	(West Mountain)			Anticl.									
	Sespe	Sespe	O.				C.S.	F-C	Poor	Poor-Well		Lentic. and Interb. Sh.	
43	VENTURA AVENUE			Anticl.	Fault.	30-60							43
	"A"	Pico	U.P.				S	F-C	Poor	Poor		Lentic. and Interb. Sh.	
	"B"	Repetto	L.P.				S	F-C	Poor	Fair		Lentic. and Interb. Sh.	
	"C"	Repetto	L.P.				S	F-C	Poor	Fair		Lentic. and Interb. Sh.	
	District III												
44	ARROYO GRANDE			Syncl.	Bit. Seal	To-30							44
	U. Santa Margarita	Santa Margarita	U.M.				S	C					
	L. Santa Margarita	Santa Margarita	U.M.				S	C					

45	CAPITAN			Dome	Fault	Low							45
	Vaqueros	Vaqueros	L.M.				S	M-C	Fair	Firm-Fri.	Silt		
	20 ft. Sand	Sespe	O.				C.S.	F-C	Poor	Well	Clay	Lentic. and Interb. Sh.	
	1st Erburu	Sespe	O.				C.S.	F-C	Poor	Well	Clay	Lentic. and Interb. Sh.	
	2nd Erburu	Sespe	O.				C.S.	F-C	Poor	Well	Clay	Lentic. and Interb. Sh.	
	3rd Erburu	Sespe	O.				C.S.	F-C	Poor	Well	Clay	Lentic. and Interb. Sh.	
46	CASMAILIA			Anticl.		Low							46
	Shale	Sisquoc	L.P.				F. Sh.						
	Chert	Monterey	U.M.				F. Ch.						
47	CAT CANYON												47
	(East)	Sisquoc	U.M.-L.P.	Anticl.	Uncon.-Lith.	Mod.	S	F	Fair	Fair	Silt	Lentic. and Interb. Sh.	
	(West)	Sisquoc	U.M.-L.P.	Anticl.	Lith.	Mod.	S	F-M	Fair	Fair		Interb. Sh.	
	(Gato Ridge)			Anticl.	Fault.	Mod.							
	L. Sisquoc	Sisquoc	U.M.-L.P.				S	VF			Silt		
	Monterey	Monterey	U.M.				F. Sh.						
48	ELWOOD			Anticl.	Fault.	Mod.							48
	Vaqueros	Vaqueros	L.M.				S	F-C	Poor	Firm-Fri.			
	Sespe	Sespe	O.				C.S.	F-C	Poor	Firm-Well		Interb. Sh.	
49	FOUR DEER												49
	Miocene		U.M.										
50	LOMPOC			Ancil.	Min. Fold								50
	U. Monterey	Monterey	U.M.				S. and F. Sh.						
51	MESA			Monocl.	Fault.								51
	Vaqueros	Vaqueros	L.M.				S	C	Poor	Uncon.	Silt		
52	MOODY GULCH			Monocl.	Fault.-Intrus.	30-90							52
	San Lorenzo	San Lorenzo	O.				S	M		Well		Interb. in Sh.	
53	SANTA MARIA			Anticl.	Min. Fault.	Mod.							53
	Sisquoc	Sisquoc	U.M.-L.P.				S. and F. Sh.						
	Santa Margarita	Santa Margarita	U.M.				F.Sh. and Ch.						
	L. Monterey	Monterey	U.M.				S					Interb. Sh.	

Table 2. Geological and mineralogical characteristics of California oil fields—Continued

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sorting	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
54	Santa Maria Valley			Monocl.	Uncon.	Mod.							54
	Santa Margarita	Santa Margarita	U.M.				F. Sh.						
	Monterey Chert	Monterey	U.M.				F.Sh. and Ch.						
	Monterey Sand	Monterey	U.M.				S	F-C		Poor-Well	Silt		
55	Sargent			Monocl.	Fault.	High							55
	Pliocene		P.				S	F					
56	Summerland			Monocl.	Fault.	To 45							56
	Basal Pliocene		L.P.				S						
	Vaqueros	Vaqueros	L.M.				S						
57	Zaca Creek			Anticl.									57
	U. Miocene	Monterey?	U.M.				F. Sh.						
	District IV												
58	Antelope Hills			Anticl.		Mod.							58
	"67-6" (Gould Sh.)	Temblor	M.M.		Min. Fault.		S	F				Interb. Sh.	
	"23-6" (Gould Sh.)	Temblor	M.M.		Min. Fault.		S	V.F.			Silt		
	"45-6" (Agua)	Temblor	M.M.		Uncon.		S	F			Silt		
59	Ant Hill			Monocl.	Fault.-Fold.								59
	Olcese	Temblor	M.M.				S	F-M		Firm, Fri.		Interb. Sh.	
	Jewett	Vaqueros	L.M.				S	F			Silt		
60	Belridge, N.			Anticl.	Min. Fault.								60
	Maricopa Shale	Maricopa	U.M.				F. Sh.						
	Temblor	Temblor	M.M.				S	F-M		Firm		Interb. Sh.	
	"R" Sand	Vaqueros?	L.M.?				S						
	Bloemer	Vaqueros	L.M.				S			Firm			
	Belridge	Vaqueros	L.M.				S	F		Poor-Well	Silt		
	"Y" Sand	Oceanic?	O.				S						

61	Belridge, S.												61
	Tulare	Tulare	Pl.	Uncon.			S						
	Maricopa Shale	Maricopa	U.M.	Anticl.			S. and F. Sh.						
62	Blackwell's Corner												62
	Vaqueros	Vaqueros	L.M.	Uncon.			S						
63	Canal			Dome		Mod.							63
	Stevens	Santa Margarita	U.M.				S	M	Fair	Firm, Fri.		Interb. Sh.	
64	Coles Levee, N.			Anticl.	Lith.	Mod.							64
	"22-1" (Stevens)	Santa Margarita	U.M.				S	F-M	Fair	Firm, Fri.		Interb. Sh.	
	U. Western (Stevens)	Santa Margarita	U.M.				S	F-M	Fair	Firm, Fri.		Interb. Sh.	
	L. Western (Stevens)	Santa Margarita	U.M.				S	F-M	Fair	Firm, Fri.		Interb. Sh.	
65	Coles Levee, S.			Anticl.	Lith.	Mod.							65
	"F-1" (Stevens)	Santa Margarita	U.M.				S	F-M	Fair	Firm, Fri.		Lentic. and Interb. Sh.	
	U. Western (Stevens)	Santa Margarita	U.M.				S	F-M	Fair	Firm, Fri.			
	L. Western (Stevens)	Santa Margarita	U.M.				S	F-M	Fair	Firm, Fri.			
66	Cymric Group												66
	(McKittrick Front)												
	Amnicola	Tulare	Pl.	Monocl.	Uncon.	Low	F. W. S.	F-C	Poor	Poor		Lentic. and Interb. Sh.	
	Franco-Western	Etchegoin	L.P.	Anticl.			S	F-M	Poor			Lentic.	
	(Salt Creek)			Anticl.									
	Amnicola	Tulare	Pl.			Low	F. W. S.	F-C	Poor	Poor		Lentic. and Interb. Sh.	
	Carneros?	Vaqueros?	L.M.		Uncon.		S	F-M				Interb. Sh.	
	(Sheep Springs)			Anticl.									
	Carneros	Vaqueros	L.M.		Fault.-Uncon.		S	F-M				Interb. Sh.	
	Oceanic	Oceanic	O.		Fault.		S	M	Well	Firm		Contin.	
	(Welport)												
	Amnicola	Tulare	Pl.	Lith.	Min. Fold.	Low	F. W. S.	F-C	Poor			Lentic. and Interb. Sh.	
	Fitzgerald	Etchegoin	L.P.	Uncon.		Low	S	F-M					
	Anderson (Carneros)	Vaqueros?	L.M.?	Monocl.	Uncon.	20	S	F-M				Interb. Sh.	
	Weston (Carneros)	Vaqueros	L.M.	Monocl.	Uncon.	20	S	F-M				Interb. Sh.	
	Weston-3 (Carneros)	Vaqueros	L.M.	Monocl.	Uncon.	20	S	F-M				Interb. Sh.	
	Phacoides	Vaqueros	L.M.	Anticl.	Min. Fault.	10-20	S	F-M			Silt-Kaolin	Interb. Sh.	
	Oceanic	Oceanic	O.	Anticl.	Min. Fault.	10-20	S	M	Well	Firm		Contin.	
	Point of Rocks	Tejon	U.E.	Anticl.	Min. Fault.	10-20	S	M	Poor	Firm		Interb. Sh.	

Table 2. Geological and mineralogical characteristics of California oil fields—Continued

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sorting	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
67	DEVIL'S DEN			Anticl.	Fault.								67
	Wagon Wheel	Wagon Wheel	O.				Sh. and S.	M-C		Firm			
68	EDISON												68
	U. Duff	Kern River	Pl.	Monocl.	Fault.	Low	C.S.	F-C	Poor	Uncon.		Lentic.	
	L. Duff	Temblor	M.M.	Uncon.		Low	S	F-C					
	Schist	Base. Complex	U.J.?	Monocl.	Fault.	Low	F. Sch.					Erratic	
69	ELK HILLS			Dome	Fault.-Lith.	Low							69
	Scalez	San Joaquin	U.P.				S					Lentic. and Interb. Sh.	
	Mulinia	Etchegoin	L.P.				S					Lentic. and Interb. Sh.	
	Stevens	Stevens	U.M.				S. and F. Sh.						
70	FRUITVALE			Terrace	Fault.-Lith.	Low							70
	Etchegoin	Etchegoin	L.P.				S	F-M					
	Chanac	Chanac	L.P.				C.S.	F-C	Poor	Poor	Clay-Silt	Lentic.	
71	GREELEY			Anticl.	Fault.	Low							71
	Stevens	Santa Margarita	U.M.				S	M-C		Firm	Silt	Lentic.	
	Vedder	Vaqueros	L.M.				S	F-C	Fair	Firm		Interb. Sh.	
72	KERN BLUFF												72
	Santa Margarita	Santa Margarita	U.M.				S						
73	KERN FRONT			Monocl.	Fault.	Low							73
	Etchegoin	Etchegoin	L.P.				S	F-M	Poor			Lentic.	
	Chanac	Chanac	L.P.				C.S.	F-C	Poor	Poor	Clay-Silt	Lentic.	
74	KERN RIVER			Monocl.	Uncon.	6							74
	Kern River	Kern River	Pl.				C.S.	F-C	Poor	Uncon.		Lentic.	
75	LOST HILLS			Anticl.		Low							75
	Etchegoin Upper	Etchegoin	L.P.				S					Interb. Sh.	
	Etchegoin Lower	Etchegon	L.P.				S					Interb. Sh.	

	(Williamson Area)			Monocl.	Lith.-Uncon.	Low							
	Amnicola	Tulare	Pl.				F. W. S.	F-C	Poor	Poor		Lentic. and Interb. Sh.	
	2nd	Etchegoin	L.P.				S	F			Silt	Lentic. and Interb. Sh.	
	3rd	Etchegoin	L.P.				S	F		Uncon.-Firm			
	4th	Etchegoin	L.P.				S	F		Poor		Lentic.	
76	McDONALD ANTICLINE			Anticl.	Fault.-Uncon.								76
	Phacoides	Vaqueros	L.M.				S	F-M			Silt		
	Oceanic	Oceanic	O.				S	M	Well	Firm			
77	McKITTRICK			Monocl.	Uncon.	15-20							77
	Amnicola	Tulare	Pl.				F. W. S.	F-C	Poor	Poor		Lentic. and Interb. Sh.	
	Olig	Etchegoin	L.P.				S	F-M	Poor			Lentic. and Interb. Sh.	
78	MIDWAY SUNSET GROUP												78
	(Buena Vista Front)			Monocl.	Uncon.								
	Scalez	San Joaquin	Pl.				S						
	(Buena Vista Hills)			Anticl.	Lith.-Fault.								
	Mulinia	Etchegoin	L.P.				S						
	27B	Reef Ridge	U.M.			15-25	S						
	(Gibson Area)												
	Scalez	San Joaquin	Pl.				S						
	Gibson	Reef Ridge	U.M.				S	M-C		Uncon.			
	(North Midway)			Monocl.	Uncon.	Mod.							
	Tulare	Tulare	Pl.				F.W.S.	F-C	Poor	Poor		Lentic. and Interb. Sh.	
	San Joaquin	San Joaquin	Pl.				S	F-C	Poor			Lentic. and Interb. Sh.	
	Etchegoin	Etchegoin	L.P.				S	F-C	Poor		Silt	Lentic. and Interb. Sh.	
	Reef Ridge	Reef Ridge	U.M.				S				Silt		
	(Republic Area)			Anticl.	Min. Fold	26-75							
	Tulare	Tulare	Pl.				F.W.S.	F-C	Poor	Uncon.			
	Etchegoin	Etchegoin	L.P.				S	F-C	Poor		Silt	Interb. Sh.	
	Republic	Temblor	M.M.				S	F-C	Well	Uncon.-Well	Silt	Interb. Sh.	
	(Santiago)			Monocl.	Fault.								
	Leutholtz		M.				S						
	(Twenty Five Hills)			Monocl.	Uncon.	20							
	A Zone	Tulare	Pl.				S	F-C	Poor	Uncon.			
	B Zone	Etchegoin	L.P.				S	F-C	Poor				
	(Williams Area)			Anticl.		40-70							
	U. Williams	McClure	U.M.				S	F		Poor		Lentic. and Interb. Sh.	
	M. Williams	McClure	U.M.				S	F		Poor		Lentic. and Interb. Sh.	
	L. Williams	McClure	U.M.				S	F		Poor		Lentic. and Interb. Sh.	
79	MOUNT POSO GROUP			Fault.	Monocl.								79
	U. Vedder	Vaqueros	L.M.				S	F-M		Uncon.-Well	Silt		
	L. Vedder	Vaqueros	L.M.				S	F					

Table 2. Geological and mineralogical characteristics of California oil fields—Continued

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sorting	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
80	Mountain View			Fault	Monocl.	Mod.							80
	Nichols	Chanac	L.P.				C.S.	F-M	Poor	Poor	Silt	Lentic.	
	Clendenen	Chanac	L.P.				C.S.	F-M	Poor	Poor	Silt	Lentic.	
	Warton	Santa Margarita	U.M.				S	M-C	Poor	Poor	Silt	Lentic.	
81	Paloma			Anticl.	Min. Fault	Mod.							81
	U. Stevens	Santa Margarita	U.M.				S	F-M	Fair	Firm-Well		Interb. Sh.	
82	Poso Creek Group			Monocl.	Uncon.								82
	Etchegoin	Etchegoin	L.P.				S	F-C	Poor	Poor	Silt	Lentic.	
	Chanac	Chanac	L.P.				C.S.	F-C	Poor	Poor	Silt	Lentic.	
83	Rio Bravo			Anticl.	Min. Fault	Mod.							83
	Rio Bravo	Santa Margarita	U.M.				S	F-M	Well	Firm			
	Vedder	Santa Margarita	U.M.				S	F-M	Well	Firm			
84	Round Mt. Group			Fault	Monocl.	5-7							84
	Jewett	Vaqueros	L.M.				S	V.F.		Firm-Well	Silt	Interb. Sh.	
	Elbe	Vaqueros	L.M.				S	V.F.		Firm Well	Silt	Interb. Sh.	
	Vedder	Vaqueros	L.M.				S	M-C		Uncon.		Lentic.	
85	Strand												85
	(West)			Dome		Mod.							
	Canal	Santa Margarita	U.M.				S	F-C	Fair	Poor-Firm		Interb. Sh.	
	1st Stevens	Santa Margarita	U.M.				S	F-C	Fair	Poor-Firm		Interb. Sh.	
	2nd Stevens	Santa Margarita	U.M.				S	F-C	Fair	Poor-Firm		Interb. Sh.	
	3rd Stevens	Santa Margarita	U.M.				S	F-C	Fair	Poor-Firm		Interb. Sh.	
	(East)			Anticl.		Mod.							
	1st Stevens	Santa Margarita	U.M.				S	F-C	Fair	Poor			
86	Tejon												86
	Chanac—Santa Margarita	Santa Margarita	U.M.	Monocl.	Uncon.		S					Lentic.	
	Reserve	Temblor?	M.M.?	Anticl.?			S						

87	Ten Section			Anticl.		Mod.							87
	Stevens	Santa Margarita	U.M.				S	F-C	Fair	Fair		Lentic. and Interb. Sh.	
88	Wasco			Anticl.		Mod.							88
	A-2	Santa Margarita	U.M.				S	M-C					
89	Wheeler Ridge			Anticl.		20-50							89
	Tulare	Tulare	Pl.				C.S.	M-C	Poor	Poor		Lentic.	
	Etchegoin	Etchegoin	L.P.				S					Lentic. and Interb. Sh.	
	Santa Margarita	Santa Margarita	U.M.				S						
	District V												
90	Coalinga Group												90
	(East)			Anticl.	Bit. Seal	Mod.							
	Temblor	Temblor	M.M.				S	F-C	Poor	Uncon.	Clay-Silt	Lentic.	
	(West)			Monocl.	Uncon.	Mod.							
	"A"	Temblor	M.M.				S	F-C	Poor	Uncon.	Clay-Silt	Lentic.	
	"B"	Temblor	M.M.				S	F-C	Poor	Uncon.	Clay-Silt	Lentic.	
	"D"	Temblor	M.M.				S	F-C	Poor	Uncon.	Clay-Silt	Lentic.	
	(Oil City)			Anticl.	Bit. Seal	Mod.							
	Moreno	Moreno	Cret.				S	F-M		Uncon.		Interb. Sh.	
91	Coalinga Extension												91
	(Northeast)			Monocl.	Uncon.	Mod.							
	Gatchell	Arroyo Hondo	E.				S	M	Well	Firm, Fri	Clean	Lentic.	
	(Nose)			Monocl.	Uncon.	Mod.							
	Gatchell	Arroyo Hondo	E.				S	M	Well	Firm, Fri	Clean	Lentic.	
92	Helm			Anticl.	Fault.-Lith.	Low							92
	Zilch	Temblor	M.M.				C.S.	F-M	Poor			Lentic.	
	Eocene	Domengine	M.E.				S	F			Clean	Lentic.	
	Weyant		Pal.?				S	F		Firm, Fri		Lentic.	
93	Jacalitos			Anticl.	Fault.-Lith.	Low							93
	U. Temblor	Temblor	M.M.				S	F-C	Poor			Lentic.	
	L. Temblor	Temblor	M.M.				S	F-C	Poor			Lentic.	

Table 2. Geological and mineralogical characteristics of California oil fields—Continued

No.	Field and Zone	Formation	Age	Structure		Dips (Deg.)	Type[1]	Size	Sort-ing	Consolid.	Clay-Silt	Continuity	No.
				Primary	Secondary								
94	Kettleman N. Dome												94
	Temblor 1	Temblor	M.M.				S	F-C	Poor	Poor-Well	Silt	Interb. Sh.	
	Temblor 2	Temblor	M.M.				S	F-C	Poor	Poor-Well	Silt	Interb. Sh.	
	Temblor 3	Temblor	M.M.				S	F-C	Poor	Poor-Well	Silt	Interb. Sh.	
	Temblor 4	Temblor	M.M.				S	F-C	Poor	Poor-Well	Silt	Interb. Sh.	
	Temblor 5	Temblor	M.M.				S	F-C	Poor	Poor-Well	Silt	Interb. Sh.	
	Vaqueros	Vaqueros	L.M.				S	F-C	Poor	Poor-Well		Interb. Sh.	
	McAdams A	Avenal	E.				S						
	McAdams B	Avenal	E.				S						
95	Pleasant Valley			Anticl.	Lith.	Mod.							95
	L. Gatchell	Arroyo Hondo	E.				S	M	Well	Well	Kaolin	Lentic.	
96	Pyramid Hills			Anticl.	Monocl.								96
	Kreyenhagen	Kreyenhagen	U.E.				S						
97	Raisin City			Anticl.	Lith.								97
	Miocene	Temblor	M.M.				C.S.	F-M	Poor			Lentic. and Interb. Sh.	
	Surfluh	Kreyenhagen	U.E.				S					Lentic. and Interb. Sh.	
	Eocene Main	Domengine	M.E.				S					Lentic. and Interb. Sh.	
	Eocene White	Domengine	M.E.				S					Lentic. and Interb. Sh.	
98	Riverdale			Anticl.	Uncon.	Mod.							98
	"66"	Temblor	M.M.				C.S.	F-M	Poor			Lentic. and Interb. Sh.	
	"68"	Temblor	M.M.				C.S.	F-M	Poor			Lentic. and Interb. Sh.	
	Courtney	Kreyenhagen	U.E.				S	F	Well	Firm		Lentic. and Interb. Sh.	

[1] Formation Type Code:

S — Marine sand or sandstone
C. S. — Continental sand or sandstone
F. W. S. — Fresh water sand or sandstone
F. SH. — Fractured shale
F. CH. — Fractured chert
CG. — Conglomerate
F. Volc. — Fractured volcanics

Table 3. *Water and oil characteristics and production from California oil fields*

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP 100°F.	Base[3]	Percent S	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
	District I															
1	ALISO CANYON			14.3	12.4	Slow	3,914	108.6	8,394							1
	Porter	30								24.2	14.3	Nap.	0.67	Tr.	285	
	Sesnon	26								22					450	
2	ALONDRA			16.3	[5]13.2		819	187.2	559							2
	Monterey									26.7						
3	BEVERLY HILLS			72.8	77.4		100	49.5	4,026							3
	Plio.-Mio. Trans.									18						
4	BREA-OLINDA			40.8	40.1	Negl.	14,846	37.8	196,183	12.3	>1250	Nap.	2.99	Abs.	600	4
	Repetto															
	Puente															
5	CHINO AREA			57.1	22.3		15	22.1	19							5
	Puente									23.0						
6	COYOTE, E.			52.0	48.7	Slow	5,121	29.8	58,816						350	6
	Hualde									18.5						
	Anaheim									22						
	2nd															
	3rd															
	Stern									25.4	21.3	Int.	1.44	Pres.		
7	COYOTE, W.			47.4	41.9	Slow	15,453	67.4	157,257							7
	Top		400-Na, HCO_3, Cl							19					550	
	Main		1100-NaCl							27.7	13.1	Int.	1.21	Pres.	550	
	"99"		700-NaCl												550	
	Emery	35	1150-NaCl, HCO_3							32					565	
	McNally									30						

Table 3. Water and oil characteristics and production from California oil fields—Continued

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP 100° F.	Base[3]	Percent S	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
8	Del Valle			31.1	10.2		9,335	81.4	10,818							8
	Sepulveda	40								35.5					High	
	Vasquez	40				Active				32.2					400	
	Videgain	40				Active				33	5.2	Int.	1.14	Pres.	500	
	Del Valle	40								34.5					700	
	Bering	40								43.5					1300	
9	Dominguez			50.6	34.6	Moderate	13,916	42.7	176,200							9
	1st	37								33	5.5	Int.	0.93	Pres.	345	
	2nd	37								29					380	
	3rd	38								31					395	
	4th	40								33					435	
	5th	41								30					570	
	6th	50								33					620	
	7th	32								30					600	
	8th	32								30					680	
10	E. Los Angeles			32.2	[5]33.1		1,219	169.0	812							10
	U. Miocene									32			0.5			
11	El Segundo			85.7	74.3	Active	391	16.4	11,986	22			3.5			11
	Congl.															
	Schist															
12	Huntington Beach			39.8	44.9		57,762	55.2	406,288							12
	(Old Field)					Slow										
	U. Bolsa	35								20.5					1000	
	L. Bolsa	35								20.5	25.5	Int.	1.26	Pres.	1000	
	U. Ashton	35								23.5					400	
	L. Ashton	40								23.5					650	
	(Offshore Field)					Slow									625	
	Tar									16						
	Jones									17.6						
	Main									24.6						

13	Inglewood			72.9	51.7	Active	12,122	37.3	163,178						800	13
	Vickers									20	29.2	Nap.	2.35	Tr.		
	Rindge									29		Nap.	1.43			
	Rubel									30	4.0	Nap.	0.91	Pres.		
	Moynier									17						
	Sentous	45								32	5.5	Nap.	1.03	Pres.		
14	Lawndale			45.8	86.7		681	86.6	1,233							14
	U. Miocene									25.9						
15	Long Beach			79.0	73.4		23,236	21.7	728,382						800	15
	U. Wilbur					Slow				22						
	L. Wilbur					Slow				22						
	Alamitos					Slow				22						
	Brown					Moderate				22.8	26.9	Int.	1.34	Pres.		
	Deep									25.0						
	De Soto									28.9						
16	Los Angeles City			58.1	80.5		175	2.6	20,170							16
	U. Puente					Active				14			1.0			
17	Montebello			84.3	74.1	Slow	6,795	21.9	149,696						600	17
	1st									20			0.8			
	2nd									25						
	3rd									27						
	4th															
	(West)					Slow									1750	
	5th									35.2	3.6	Int.	0.28	Pres.		
	6th									36						
	7th									36						
	8-1									35						
	8-2															
18	Newhall Group			35.4	46.0		188	7.8	6,024							18
	(Elsmere Canyon)									15						
	Pico															
	Eocene															
	(Pico Canyon)									37.3						
	Top															
	Central															
	Lower															
	(Towsley Canyon)									19						
	Modelo															
	(Tunnel Area)									19						
	Pico															
	(Whitney Canyon)									13						
	Saugus															
	Pico															
	Eocene															
	(Wiley Canyon)					Rapid				28						
	Modelo															

Table 3. Water and oil characteristics and production from California oil fields—Continued

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP	Base[3]	Percent S	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
19	Newhall-Potrero			1.4	0.2		7,277	138.1	15,248						575	19
	1st	40				Negl.				32.7	5.8	Int.	0.52	Pres.		
	2nd	40				Negl.										
	3rd	40				Negl.				34						
20	Newport, W.			19.4	[6]5.4		6,370	38.6	5,990							20
	"A"	15								12.5		Nap.	1.99	Abs.		
	"B"	15								20.0						
	"C"					Rapid				15.0						
	Lyddon									16.1						
21	Oak Canyon			5.2	4.5		1,992	116.7	3,279				1.0			21
	Wickman					Active				22					35	
	Gilmour					Active										
	Max.-Weaver					Active										
	Lechler					Active				34						
22	Playa Del Rey			86.0	80.7		2,003	17.2	51,770						600	22
	Upper					Active				20						
	Schist Congl.					Active				22.5			3.5			
23	Potrero			62.3	45.6	Active	1,124	43.8	6,418				2.0			23
	Pico									33						
	U. Repetto									38						
	M. Repetto									43						
24	Richfield			51.7	40.5		6,269	20.3	111,710						800	24
	Chapman	37	340-NaCl			Slow				19			1.60			
	Kraemer		1200-NaCl			Slow				22.3	71.5	N.I.	1.09	Pres.		
	(Kraemer Area) Kraemer									19						

25	ROSECRANS			58.0	43.0		4,599	25.1	62,083						1800	25
	(Athens Area)															
	U. Athens					Rapid				42						
	L. Athens					Rapid										
	U. Howard Park					Rapid				37.8	3.5	Int.	0.53	Pres.		
	L. Howard Park					Rapid				37						
	L. Zins									35						
	O'Dea									37						
	(Main Street)															
	Padelford					Rapid										
	U. Maxwell					Rapid										
	L. Maxwell					Rapid				38.8						
	Hodge					Rapid				38.8						
	Zins									33.8						
	O'Dea									35.7						
26	SALT LAKE			90.4	80.7	Moderate	135	32.4	43,026							26
	Repetto									17						
27	SANTE FE SPRINGS			80.5	74.8		15,377	29.8	520,664						885	27
	Foix					Active				26						
	Bell	21				Active				29						
	Meyer		600			Negl.				32						
	Nordstrom		650			Active				34						
	Buckbee		1160			Rapid				34						
	O'Connell		1450			Active				34						
	Clark-Hath		1690			Rapid				34.2	3.8	Int.	0.26	Pres.		
28	SEAL BEACH			73.7	78.3		11,539	66.0	111,698						635	28
	Bixby									23.8						
	Selover									24.2	30.6	Int.	1.23	Pres.		
	Wasem									26.5						
	McGrath									26.0						
29	TORRANCE			42.5	35.6		7,997	11.2	122,887						365	29
	Main					Negl.				22.8	35.8	Int.	1.62	Pres.		
	Harbor City					Negl.										
	Del Amo					Negl.				13.8	1060	Nap.	3.29	Abs.		
30	TURNBULL			60.8	21.3		104	20.3	490							30
										24.0						
31	WHITTIER			76.6	76.3		974	6.8	21,509				1.2			31
	1st					Active				18						
	2nd					Active				18						
	3rd					Active				19						
	4th					Active				18						
	L. Puente					Active				27						

Table 3. Water and oil characteristics and production from California oil fields—Continued

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP 100° F.	Base[3]	Percent S	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
32	WILMINGTON			18.8	9.2	Moderate	133,719	72.3	394,204							32
	Tar	22								13			2.0		75	
	Ranger	30								19			1.7		150	
	U. Terminal	30								25	20.4	Nap.	1.24	Pres.	300	
	L. Terminal	30								28			0.9		300	
	Ford	40								29			0.6		450	
	"237"	45								31			0.6			
	District II															
33	BARDSDALE AREA			16.8	22.9			9.0	17,616							33
	(Bardsdale)					Negl.	790						2.0			
	Sespe									27						
	Eocene									23						
	(Shields Canyon)					Negl.				35.1		I.P.	1.5		2500	
	Top						941									
	Intermediate															
	Deep															
	(Torrey Canyon)					Negl.										
	Sespe									27.5						
34	MONTALVO, W.			4.1	[5]2.1		602	137.8	91							34
	Repetto															
35	OJAI GROUP			20.7	28.9	Negl.	660	10.8	3,527							35
	(Sulphur Mt.)									15.5						
	(Sissar Creek)									19.0						
	(Sissar Silverthread)									18.5						
	(U. Ojai Valley)															
36	OXNARD		1300	2.5		Negl.	1,380	254.2	2,691	8-13			7.5			36
	Vaca Tar															
	Brown Shale															
	Frac. Volc.															

37	PIRU AREA			15.6	29.3	Negl.		42.4	19,932							37
	(Hopper Canyon)						209			29.0						
	(Modelo)						6			26.1						
	(Temescal)						549			22.0			0.7			
38	RINCON AREA			16.1	18.0	Negl.		73.4	47,154						1000	38
	(Padre Canyon)						6,192			29.1			0.5			
	(Rincon)						3,334			30			1.7			
	Top															
	Intermediate															
	Miley									29.9	9.7	Int.	1.11	Pres.		
	(San Miguelito)						4,689			31.7	6.8	Int.	0.93	Pres.		
39	SANTA PAULA GROUP			63.9	65.6			3.2	2,329							39
	(Adams Canyon)					Negl.				25						
	(Ex-Mission)					None	29			25.2			1.8			
	(Salt Marsh)					Negl.				25						
	(Timber Canyon)					None				28.7						
	(Wheeler Canyon)					Negl.	38			28						
40	SESPE CANYON GROUP			26.4	30.6	Negl.	223	10.8	3,488							40
	(Sespe Forks)									20.6			0.9			
	Sespe															
	U. Tejon															
	(Topatopa)									33.3						
	L. Vaqueros															
	U. Sespe															
41	SIMI			55.5	41.2	Slow?	162	2.7	2,347	32			0.61			41
	L. Sespe															
	Llajas															
42	SOUTH MOUNTAIN			8.4	4.4	Negl.	5,741	40.6	29,544							42
	L. Sespe									23.9			3.1		2750	
	(West Mountain)						1,081									
	Sespe									22.5						
43	VENTURA AVENUE			17.3	14.5	Active	51,813	99.7	347,019						2600	43
	"A"	27								31						
	"B"	27								30.5						
	"C"	30								32	9.9	Int.	1.17	Pres.		

Table 3. Water and oil characteristics and production from California oil fields—Continued

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP	Base[3]	Percent	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
	District III															
44	ARROYO GRANDE			32.0	7.6	Slow?	114	7.9	1,471							44
	U. Santa Margarita									16						
	L. Santa Margarita									22						
45	CAPITAN			78.9	45.5	Moderate	2,534	44.6	12,403						380	45
	Vaqueros		70							22	48.5	N.I.	0.69	Pres.		
	20 ft. Sand		150-700													
	1st Erburu		150-700							42.1			0.4			
	2nd Erburu		150-700													
	3rd Erburu		150-700													
46	CASMAILIA			56.6	14.2	Active?	986	51.2	15,648	10.3			3.5			46
	Shale															
	Chert															
47	CAT CANYON			37.5	19.2			121.3	52,965							47
	(East)						612			12.0						
	(West)					Active	16,326			14.6	>1240		5.21	Abs.		
	(Gato Ridge)					Active	3,740			12.3			5.3			
	L. Sisquoc															
	Monterey															
48	ELWOOD			59.7	71.7		7,242	106.3	81,571						420	48
	Vaqueros	28	1200			Rapid				33.7	2.7	Int.	0.18	Pres.		
	Sespe		1000			Rapid				32.6						
49	FOUR DEER				[5]2.1		647	81.0								49
	Miocene															
50	LOMPOC			51.6	43.5	Active	6,632	79.4	15,748							50
	U. Monterey									20.5			4.1			

51	Mesa			94.5	92.3	Rapid	93	5.7	3,593							51
	Vaqueros	30	1100							17			0.5			
52	Moody Gulch			2.2	10.5	None?	4	4.8	62							52
	San Lorenzo									42		Par.?				
53	Santa Maria			58.9	60.6		4,612	21.6	106,698						1880	53
	Sisquoc									16						
	Santa Margarita									23	49.2	Nap.	2.63	Pres.		
	L. Monterey									26						
54	Santa Maria Valley			48.8	28.7	Active	20,779	46.7	88,147						900	54
	Santa Margarita									15.9						
	Monterey Chert	60	1400							16	>1200		5.06	Pres.		
	Monterey Sand															
55	Sargent			0	0	None	0	0	784							55
	Pliocene									17						
56	Summerland			56.5	30.5	Active?	5	4.9	3,183	18					V. Low	56
	Basal Pliocene															
	Vaqueros															
57	Zaca Creek			21.6	[6]20.6		1,610	221.3	563							57
	U. Miocene									8						
	District IV															
58	Antelope Hills		370-625	74.2	26.2	Active	1,224	55.7	3,510							58
	"67-6"	26								16.6			0.56		V.High	
	"23-6"	26								16.7					200	
	"45-6"	26													200	
59	Ant Hill			43.6	[6]24.9		1,045	35.8	1,475							59
	Olcese					Slow				13					V. Low	
	Jewett					Active				39					450	
60	Belridge, N.			39.2	45.5		3,769	56.9	55,647				0.6			60
	Maricopa Shale									13.7						
	Temblor		2240			Active				41.1	1.7	Int.	0.1	Pres.		
	"R" Sand	60								52					V.High	
	Bloemer	35				Slow				35.9					600	
	Belridge	35				Slow				35.9					600	
	"Y" Sand	50								31					750	

Table 3. Water and oil characteristics and production from California oil fields—Continued

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP 100° F.	Base[3]	Percent S	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
61	BELRIDGE, S.			45.8	32.6	Slow?	8,816	12.8	44,270							61
	Tulare	20								23.8	17.1	Nap.	0.86	Abs.		
	Maricopa Shale									31						
62	BLACKWELL'S CORNER			87.6	[6]37.9	Negl.	143	5.3	269							62
	Vaqueros									13						
63	CANAL			13.2	11.5		1,945	72.8	13,592							63
	Stevens	38				Slow				37.5		Int.	0.7	Pres.	700	
64	COLES LEVEE, N.			3.3	1.5		16,088	180.1	40,424						600	64
	"22-1"	38				Slow										
	U. Western	40				Slow				44	4.8	Int.	0.5	Pres.		
	L. Western	40				Slow				31						
65	COLES LEVEE, S.			5.1	2.6		3,144	130.0	13,931				0.7			65
	"F-1"	40				Slow				44.5						
	U. Western	40				Slow				49.7					900	
	L. Western	40				Slow				49.7					900	
66	CYMRIC GROUP			38.9	[6]36.1	Negl.?		82.1	25,172							66
	(McKittrick Front)						2,803						1.0-2.0			
	Amnicola									13						
	Franco-Western									15						
	(Salt Creek)	25					6,037									
	Amnicola									18						
	Carneros									17					155	
	(Sheep Springs)															
	Carneros						923			24						
	Oceanic									41					4000	
	(Welport)						17,481						1.0			
	Amnicola									12						

	Fitzgerald									31						
	Anderson									32						
	Weston									32						
	Weston-3									32						
	Phacoides		1400-Na, Ca, Cl							33						
	Oceanic		1170-NaCl			Active				36.9					580	
	Point of Rocks									46					3000	
67	DEVIL'S DEN			39.0	66.7	Slow?	43	8.5	130							67
	Wagon Wheel									19.6			0.7			
68	EDISON			39.6	46.0		13,208	47.9	27,093							68
	U. Duff		130-HCO₃			Slow				17.9	395	Nap.	0.68	Abs.		
	L. Duff					Slow				21.1						
	Schist															
69	ELK HILLS			63.0	57.4		6,277	66.6	197,505							69
	Schalez	31				Active				22.5					150	
	Mulinia	41				Active				22.5	21.6	Nap.	0.69	Abs.	150	
	Stevens	41								39.7					750	
70	FRUITVALE			67.9	39.0		6,408	40.4	42,728							70
	Etchegoin					Rapid				15.5					50	
	Chanac					Negl.				24.2	26.6	N.I.	0.60	Pres.	50	
71	GREELEY			23.0	14.9		13,929	168.1	34,907							71
	Stevens	34	1170-HCO₃			Active				36.3	3.0	Int.	0.29	Pres.	800	
	Vedder	34				Active				34.3					890	
72	KERN BLUFF			15.6			1,064	44.8	144							72
	Santa Margarita									14						
73	KERN FRONT			72.6	60.6		9,434	14.4	67,384							73
	Etchegoin					Active				15.1	620	Nap.	0.89	Abs.		
	Chanac					Slow				18						
74	KERN RIVER			92.8	96.0		12,770	5.0	298,098							74
	Kern River	25	Fresh			Active				13.3	1060	Nap.	1.07	Abs.		
75	LOST HILLS			75.9	84.2		7,885	13.6	61,108							75
	Etchegoin Upper					Negl.				29.5	7.2	N.I.	0.66	Abs.		
	Etchegoin Lower					Negl.										

Table 3. *Water and oil characteristics and production from California oil fields—Continued*

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP	Base[3]	Percent S	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
	LOST HILLS—Continued															
	(Williamson Area)															
	Amnicola									18.4	100	Nap.	0.99	Abs.		
	2nd					Slow										
	3rd															
	4th															
76	McDONALD ANTICLINE			81.7	[6]58.8		168	11.4	67	16						76
	Phacoides															
	Oceanic															
77	McKITTRICK			78.5	82.5	Slow	2,803	16.5	95,802	14.2			1.0-2.0			77
	Amnicola															
	Olig	25														
78	MIDWAY-SUNSET GROUP			54.3	60.3		88,245	24.4	1,082,348							78
	(Buena Vista Front)															
	Scalez					None				26.7	10.0	Nap.	0.59	Abs.		
	(Buena Vista Hills)												0.9			
	Mulinia					None				25					350	
	27B	30								31					530	
	(Gibson Area)					Slow										
	Scalez															
	Gibson									21.6						
	(North Midway)					Slow										
	Tulare									17						
	San Joaquin									17						
	Etchegoin									20.3	49.0	Nap.	0.88	Abs.		
	Reef Ridge									16						
	(Republic Area)					Slow										
	Tulare									17						
	Etchegoin															
	Republic									19.2			1.03			
	(Santiago)															
	Leutholtz									21			1.4			
	(Twenty Five Hills)					Slow										
	A Zone															
	B Zone															

	(Williams Area)					Active										
	U. Williams									13.8						
	M. Williams															
	L. Williams															
79	MOUNT POSO GROUP			94.0	80.9		12,937	25.5	99,049							79
	U. Vedder	31				Rapid				15.2	343	Nap.	0.65	Abs.		
	L. Vedder					Active										
80	MOUNTAIN VIEW			46.3	55.0		3,563	27.1	49,918						500	80
	Nichols		Cl-60			Active				26.4						
	Clendenen		Cl-200			Active				26.6	7.9	Int.	0.44	Pres.		
	Warton		530-NaCl			Active				27.3						
81	PALOMA			2.3	1.3		11,601	198.5	16,302							81
	U. Stevens		45			Slow				52	>1.5	Int.	0.10	Pres.	1200-5600	
82	POSO CREEK GROUP			78.5	56.0		3,561	16.6	12,737	13.5			0.8			82
	Etchegoin					Slow										
	Chanac					Slow										
83	RIO BRAVO			10.6	4.4		12,040	139.2	45,099						1040	83
	Rio Bravo	28				Slow				38						
	Vedder					Slow				38.2	2.7	Int.	0.22	Pres.		
84	ROUND MT. GROUP			94.3	86.7		7,711	22.4	54,575							84
	Jewett					Slow				22.5	20.7	Nap.	0.43	Abs.		
	Elbe					Slow				19						
	Vedder					Rapid				14						
85	STRAND			65.4	25.1		1,202	61.6	5,725							85
	(West)									34		Nap.	0.8		650	
	Canal	35				Slow										
	1st Stevens	32				Slow										
	2nd Stevens	32				Slow										
	3rd Stevens	30				Slow										
	(East)									34		Nap.	0.8		650	
	1st Stevens	42				Slow										
86	TEJON			29.3	[5]21.4		3,128	41.7	2,605	18.6			0.48			86
	Chanac-Santa Marg.															
	Reserve															

Table 3. *Water and oil characteristics and production from California oil fields—Continued*

No.	Field and zone	Per-cent water sat.	Salinity (G.P.G.)	Percent water prod.		Water encroach.	Oil production			Gravity °A.P.I.	Viscosity CP	Base[3]	Percent S	Wax	G.O.R.[4]	No.
				7-1-48	7-1-43		Daily[1]	Per well[2]	Total[2]							
87	TEN SECTION			12.2	5.7		6,975	75.9	43,035							87
	Stevens	38				Slow				36.4	3.0	Int.	0.37	Pres.	700	
88	Wasco			91.9	24.8		194	40.9	4,669							88
	A-2	32				Rapid				35			0.55		400	
89	WHEELER RIDGE	25		20.4	20.4		368	7.4	4,522	23.5			0.8			89
	Tulare															
	Etchegoin															
	Santa Margarita															
	District V															
90	COALINGA GROUP			51.8	44.5			17.6	426,829							90
	(East)						18,740			20.7	35.0	Nap.	0.51	Abs.		
	Temblor	65	400-HCO_3			Slow										
	(West)		300-600-HCO_3			Slow	7,046			15.4	257	Nap.	0.71	Abs.		
	"A"	65														
	"B"	65														
	"D"	65														
	(Oil City)						79									
	Moreno					Negl.				34		Par.				
91	COALINGA EXTENSION			36.3	7.5			344.6	152.259						600	91
	(Northeast)						9,893			26.9			0.6			
	Gatchell	21	140-Na, Cl, HCO_3			Active										
	(Nose)															
	Gatchell	21	140-Na, Cl, HCO_3			Active	52,897			31.1	5.8	Int.	0.31	Pres.		
92	HELM			39.0	37.3			66.9	7,813							92
	Zilch	30				Active				60.8	>1.4	Int.	0.10	Pres.		
	Eocene	25				Active				31	4.9	Int.	0.21	Pres.		
	Weyant					Active				31					600	

93	JACALITOS			15.6	0.7		3,346	66.1	8,034	38.6	2.7	Int.	0.34	Pres.	300	93
	U. Temblor	55				Negl.										
	L. Temblor	55				Negl.										
94	KETTLEMAN N. DOME			41.3	25.9		35,070	119.1	344,134							94
	Temblor 1	30				Negl.										
	Temblor 2	30	2350-NaCl			Negl.				36.5					350	
	Temblor 3	30	1750-NaCl			Slow									450	
	Temblor 4	30				Negl.									600	
	Temblor 5	30	1750-Na, Cl, Ca			Negl.				34	5.1	Int.	0.50	Pres.	1000	
	Vaqueros	50	1750-Na, Cl, Ca			None				38					750	
	McAdams A	45	600-Na, Cl, HCO_3												1050	
	McAdams B	45													1050	
95	PLEASANT VALLEY			25.6	0.7		3,366	176.0	5,932							95
	L. Gatchell	45	130-Na, SO_4, Cl, HCO_3			Active				29.9	10.0	Int.	0.35	Pres.	700	
96	PYRAMID HILLS			21.9			219	10.7	457	18						96
	Kreyenhagen															
97	RAISIN CITY			60.8	24.8		3,350	83.7	5,322							97
	Miocene	25				Active				25.7	18.0	Int.	0.41	Tr.	300	
	Surfluh	35				Active				28.5					300	
	Eocene Main	35				Active				29					500	
	Eocene White	35				Active				24.5					300	
98	RIVERDALE			25.8	1.0	Active?	3,016	76.3	7,403							98
	"66"	30								36	2.4	Int.	0.22	Pres.	2300	
	"68"	30								36					850	
	Courtney	32								37					700	

---

[1] Barrels per day

[2] Thousands of barrels

[3] Base of crude oil: Par. (Paraffin); I. P. (Intermediate Paraffin); Int. (Intermediate); Nap. (Naphthene); N. I. (Naphthene-Intermediate).

[4] Estimated formation gas-oil ratio

[5] 1-1-48

[6] 1-1-47

Summary

In summarizing the foregoing analysis of the characteristics of California oil fields, the following factors appear to be unfavorable for water-flooding: faulted and irregular structures; interbedded and lenticular sands, some with a high clay content; low and variable permeability of producing sands; possibly high water saturation of producing formations; low gravity and high viscosity crude oil. Factors favorable to water-flooding in California include: high demand and high selling price for crude oil; high porosity and probable high residual oil saturation of reservoir sands; abundance of potentially usable wells in older fields; limited edgewater encroachment in some areas.

MINES AND MINERAL RESOURCES OF BUTTE COUNTY, CALIFORNIA

By J. C. O'Brien *

OUTLINE OF REPORT

Page
ABSTRACT ---------- 417
INTRODUCTION ---------- 418
  Geography ---------- 418
  Topography and climate ---------- 418
  Transportation ---------- 419
  Geology ---------- 419
MINES AND MINERAL RESOURCES ---------- 420
  Asbestos ---------- 421
  Chromite ---------- 421
  Clay ---------- 421
  Coal ---------- 421
  Copper-zinc ---------- 421
  Gems ---------- 426
  Gold ---------- 426
  Lead-silver ---------- 433
  Limestone ---------- 433
  Manganese ---------- 434
  Mineral paint ---------- 434
  Mineral springs ---------- 434
  Natural gas ---------- 434
  Platinum-group metals ---------- 434
  Soapstone ---------- 434
  Stone (miscellaneous) ---------- 435
TABULATED LIST OF MINES ---------- 440

Illustrations

Plate 19. *A*, Butte County Gravel Plant, East Biggs, Butte County. *B*, Butte Creek Rock Company sand and gravel plant, Butte County. *C*, Central Sand and Gravel Plant, on Dry Creek, Butte County ---------- 420-421
20. *A*, Henry J. Kaiser Company gravel plant south of Oroville, Butte County. *B*, Lancha Plana Gold Dredging Company dredge No. 3, on Butte Creek east of Chico, Butte County ---------- 420-421
21. *A*, Surcease (Big Bend) mill, Butte County. *B*, Surcease mine plant yard, Butte County ---------- 420-421
22. *A*, Yuba Consolidated Gold Fields bucket-line dredge No. 1, Oroville district, Butte County. *B*, Yuba Consolidated Gold Fields dredge No. 3, Oroville district, Butte County ---------- 420-421
23. Map showing mines and mineral deposits of Butte County, California ---------- In pocket

ABSTRACT

Butte County, situated in north-central California, has a land area of 1,722 square miles. Its western boundary is in the flat Sacramento Valley, and the Sierra Nevada trends northwestward along its eastern boundary. The western half of the county is covered with alluvial gravel. The Sierra Nevada has a core of granite and granodiorite which has intruded the meta-volcanics and meta-sedimentary slates, quartzites, and limestones. These metamorphics were intruded by serpentine in some areas and covered by Pliocene and Miocene basalt in other areas.

---

* District Mining Engineer, Redding District, California State Division of Mines. Manuscript submitted for publication December 1, 1948.

Gold placer mining of some of the rich stream gravels and ancient channels has been active since the early days of the gold rush. The first floating bucket-line edge was built and operated in the Oroville district. The fact that some of the gravel has been profitably worked a second and third time shows that continual progress is being made in dredging techniques. Gold dredging was the principal mining industry at the time the survey was made for this report.

The gold quartz mines have been closed because of the high cost of labor and materials. A zinc-copper mine in the Big Bend district operated for three years during the war and produced a substantial amount of copper, zinc, and lead for the war effort. A small amount of asbestos and chromite was mined in the Magalia district. Gravel plants have been active, using the dredge tailings as raw material. The sand and gravel produced were second to gold in value of production.

Richardson Mineral Springs east of Chico has been developed into a very popular resort and attracts many people throughout the year.

INTRODUCTION

Geography

Butte County is situated in the north-central part of California. It derives its name from three prominent peaks known as the Marysville Buttes which rise from a short range of mountains in the northwestern part of Sutter County. It is bounded on the north by Tehama County, on the east by Plumas County, on the southeast by Yuba County, on the south by Sutter County, and on the west by Glenn and Colusa Counties. It has a land area of 1,722 square miles, which includes 896,045 acres of privately owned land, 683,852 acres in farms, and 212,193 acres in forest and other types of land. Public lands include 165,555 acres, of which 111,524 acres are in the Plumas and Lassen National Forests and State Parks.

Oroville, the county seat, is located on the Feather River in the south-central part of the county. The 1940 census reported a population of 42,840 for Butte County. The population was estimated to be 52,100 in 1946.[1]

Topography and Climate

The western half of Butte County is in the flat Sacramento Valley. It has a minimum elevation of 60 feet, but the land rises from the low foothills in the central portion to ridges, with a maximum elevation of 6,650 feet, in the Sierra Nevada which forms the eastern boundary. The mountains are very rugged, and the North Fork, Middle Fork, and South Fork of Feather River flow in deep canyons. Feather Falls of Fall River, a tributary to Middle Fork, is 640 feet high and is exceeded in California only by the falls in Yosemite National Park. About 15 miles northeast of Oroville, Bald Rock, a granite cliff, rises to an elevation of 3,300 feet above a canyon.

The Sacramento and Feather Rivers and their tributaries are the principal streams which drain and irrigate Butte County.

The climate varies with the elevation. In the flat western portion, the summers are long, hot, and dry, but are much cooler in the high northeastern portion. Rainfall varies from 20 to 30 inches annually. Snowfall is heavy in the higher mountains, but rare in the valleys.

---

[1] California Blue Book, p. 477, 1946.

Vol 45

Transportation

The main line of the Southern Pacific Railroad runs northwestward through western Butte County and has branch lines from Honcut to Oroville, and from Chico east to Sterling City. The Western Pacific Railway enters Oroville from the south and follows the scenic Feather River Canyon northeastward into Plumas County. The Northwestern Pacific Railway connects Chico and Oroville with Sacramento. Bus and highway freight lines operate over the Pacific and Feather River highways. There are 1,835 miles of state and county roads of which 313 miles are paved.[2]

Geology

The geology of Butte County is shown on the Geologic map of California [3] on a scale approximately 1 inch to 8 miles. The western half of the county is covered by alluvial gravel, sand, and sediments which slope gently westward from the foothills of the Sierra Nevada to the broad Sacramento Valley. The Sierra Nevada which trends northwestward through the eastern half of the county has a core of granite and granodiorite which has intruded the older meta-volcanics and meta-sedimentary slates, quartzites, and limestones. These older metamorphics have been in turn intruded in places by serpentine and in other places covered by Pliocene and Miocene basalt flows.

The geologic history of the Chico quadrangle has been described by Lindgren,[4] and the following summary has been extracted from his paper:

"In the adjoining Bidwell Bar quadrangle the principal features are three large areas of granitic rocks representing the last intrusion into an older series of Carboniferous clay slates (Calaveras formation), and large masses of greenstone and greenstone schists, which are altered products of various basic rocks, generally mapped together under the term amphibolites. These greenstones, which in most places form prominent ridges, extend over into the Chico quadrangle, where they dip below the Neocene volcanic tuffs of western Butte and northeastern Tehama Counties. A belt of serpentine is exposed in West Branch of Feather River at Magalia and continues thence northwestward towards the Lucretia mine. Clay slates, containing fossil plants of Jurassic age, are exposed below Monte de Oro, on the north side of the Feather River. Farther west a belt of Carboniferous slates and limestones of the Calaveras formation is exposed to the northeast of Pentz ranch. It is possibly the same belt of clay slates which outcrop in the canyon of Butte Creek above Helltown; serpentine and greenstones appearing farther up. Intrusive diorites occur near Lovelock and Powelton in the northeastern part of the quadrangle about Inskip and Chaparral on the heads of Butte and Chico Creeks. There is another area of Carboniferous slates (Calaveras formation) which according to Diller, extend up into the Lassen Peak quadrangle. A narrow area of the same slates is exposed in Deer Creek, 6 miles east of Butte Meadows.

"The amphibolite from Oroville to Oregon City and Cherokee contains a number of quartz veins, of which the Banner is the best known, and many small seams rich in gold. At Yankee Hill is the Hearst mine which is supposed to have yielded $1,500,000 from small shoots and stringers, and many other small pocket mines have been worked in the same vicinity. North of Sawmill Peak, at Magalia, is another belt of quartz veins, the northward continuation of which is believed to have enriched the Perschbaker channel. Most of the veins are small and pockety. The whole 'Bedrock series' in the Chico quadrangle is impregnated with gold-bearing seams and veins. The gold was con-concentrated into numerous Neocene streams which have been preserved underneath the covering lavas along the western margin of the belt. Many of the recent streams were also rich and have been extensively mined in the early days. The bars along the Feather River were long worked and reworked by placer miners. The West Branch was likewise rich. . . .

---

[2] California Blue Book, p. 479, 1946.

[3] Jenkins, O P., Geologic map of California, scale 1:500,000: California Div. Mines, 1938.

[4] Lindgren, Waldemar, The Tertiary gravels of the Sierra Nevada of California: U. S. Geol. Survey Prof. Paper 73, pp. 84-93, 1911.

"At Oroville and north of it the greenstone ridges rise sharply from the sediments of the valley, but their direction changes here to more nearly north. North of Cherokee the principal ridge follows the east side of West Branch up towards Magalia, rising to a height of a thousand feet above the gently sloping tuff plateau on the west side of that stream. The same conditions, more or less pronounced, continue northward to Inskip and Chaparral; the latter situated in the Lassen Peak quadrangle. The bedrock ridge here rises to elevations of over 5,000 feet, and the Tuscan tuff spreads westward about 1,000 feet lower. North of this point the lavas of the Lassen Peak quadrangle cover everything. At Oroville, where the present river has cut through the ridge and exposed the Neocene surface on the north side, the slope of the surface close to the valley is 1,000 feet in a little more than 3 miles. Between Cherokee and Pentz the escarpment is very well marked, and the section from Magalia to Sawmill Peak shows a rapid rise of 1,500 feet of the Neocene surface. West of Magalia, as shown by the exposure in Butte Creek, the slope is less steep, but the bedrock soon disappears beneath the lavas. . . .

"There was no Neocene river corresponding to the present Feather River. One of the numerous small streams taking its place was that whose gravels have been mined so successfully at Cherokee, 10 miles north of Oroville. Neocene shore gravels appear on a north-northwestward-trending line from Cherokee to Mineral Slide and Helltown on Big Butte Creek. The northeastern part of the Chico quadrangle was drained by a very well defined channel deeply cut through the greenstone ridge. Its upstream course runs from the Mammoth shaft, two miles west of Magalia, to the Parry incline, three miles north of the same place, and thence up below heavy covering volcanic masses to the northeast corner of the quadrangle.

"West of this deep channel are a number of small but rich channels draining westward across the present canyon of Big Butte Creek, north of Nimshew."

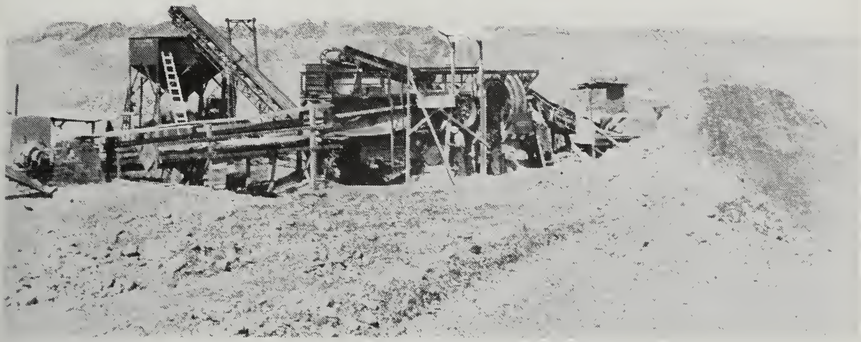
MINES AND MINERAL RESOURCES

The first successful floating bucket-line dredge was put into operation on the Feather River at Oroville, on March 1, 1898. This was the beginning of a new method of placer mining which rapidly developed and spread throughout northern California. The placer gold produced by the dredges on the Feather River and its tributaries and by the hydraulic and drift mines in the Cherokee and Magalia districts, has been the chief source of mineral wealth in Butte County. There is a recorded production of more than $71,000,000 in gold since records were first compiled in 1880, but the grand total must be several times that amount, for the early-day placers were very rich. Miscellaneous stone, a by-product of the dredges, is next to gold in value of production. It amounted to $147,534 in 1946. The platinum-group metals have been produced as by-products of placer gold mining. Except when the Big Bend mine was in operation (1942-45), copper and lead have been produced mainly as by-products of the gold quartz mines.

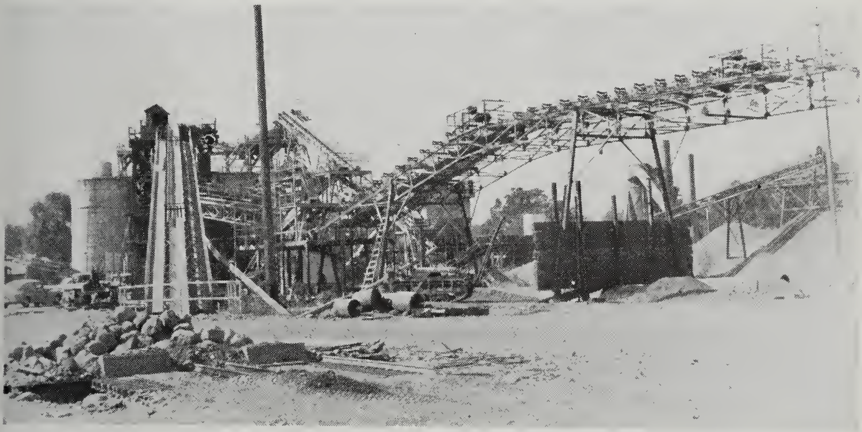
Other minerals that have been produced in the county include asbestos, chromite, clay, coal, diamonds, limestone, manganese, mineral paint, mineral water, natural gas, medicinal salt, and soapstone. The mineral production of Butte County, from 1880 to 1947, is shown in the accompanying table. Earlier reports[5] describing the mines and mineral resources of Butte County were prepared by Logan, Miner, and Waring.

---

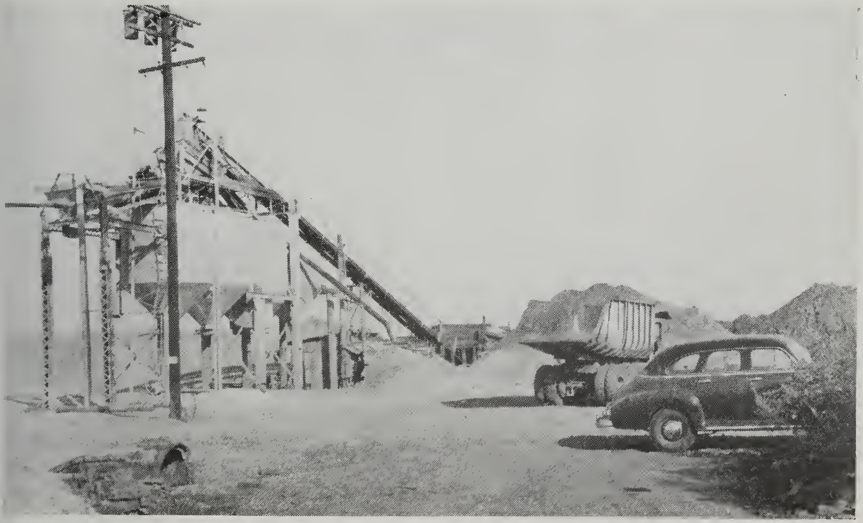
[5] Logan, C. A., Butte County: California Min. Bur. Rept. 24, pp. 173-210, 1928 . . . Rept. 26, pp. 360-412, 1930.
Miner, J. A., Butte County: California Min. Bur. Rept. 10, pp. 124-146, 1890.
Waring, C. A., Butte County: California Min. Bur. Rept. 15, pp. 181-225, 1916.



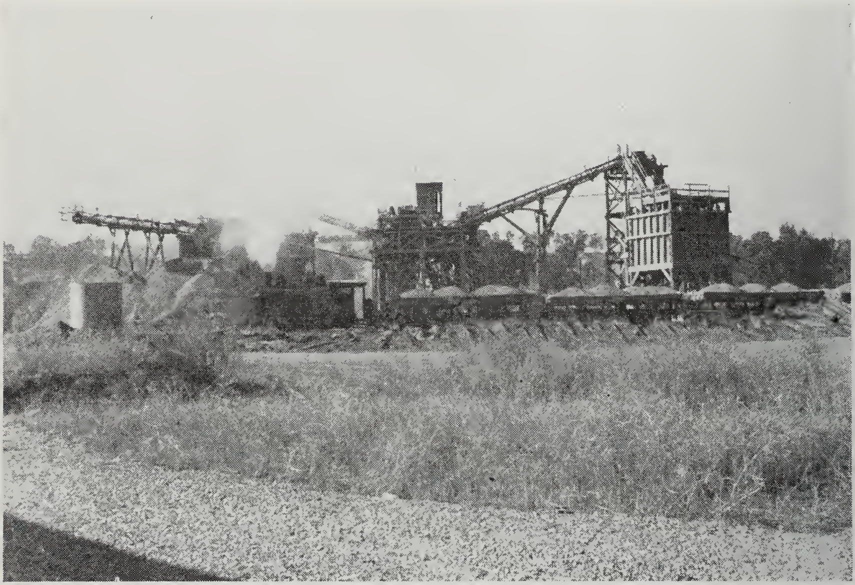
A, BUTTE COUNTY GRAVEL PLANT, EAST BIGGS, BUTTE COUNTY



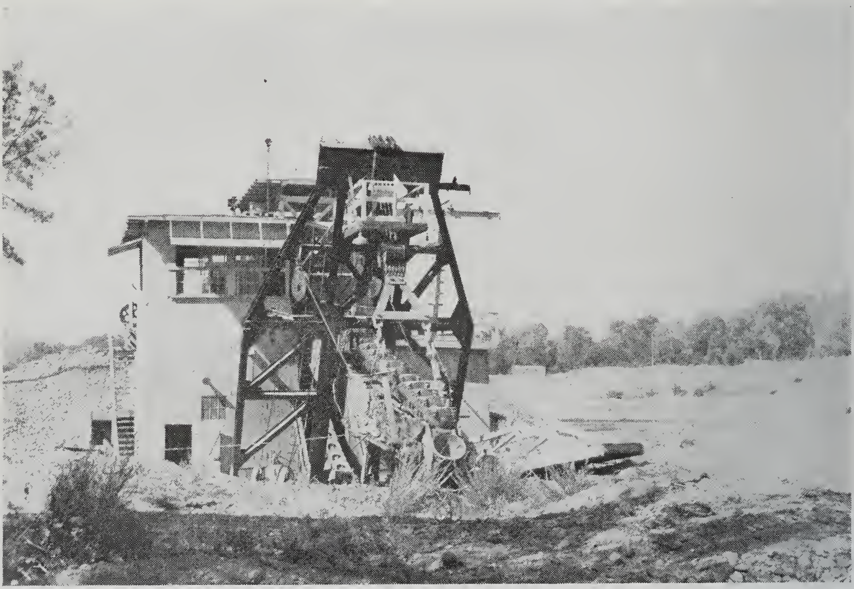
B, BUTTE CREEK ROCK COMPANY SAND AND GRAVEL PLANT
BUTTE COUNTY



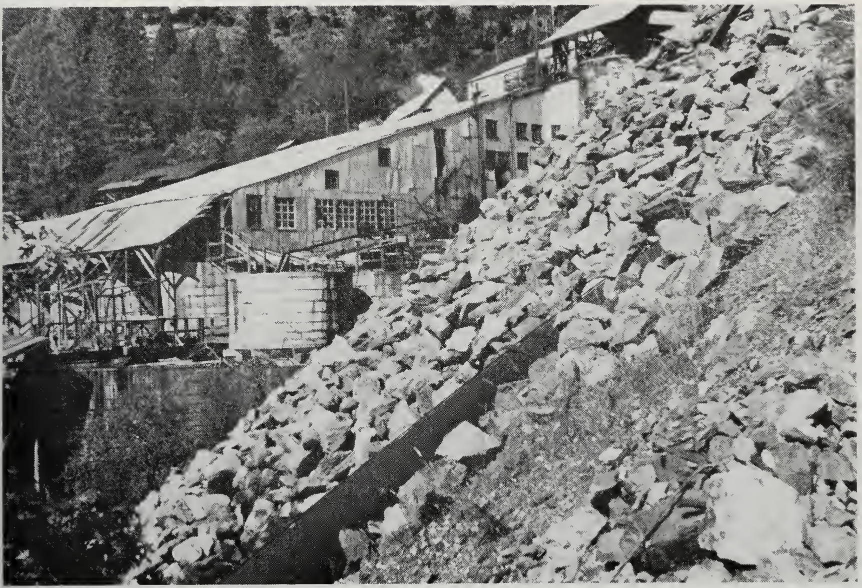
C, CENTRAL SAND AND GRAVEL PLANT, ON DRY CREEK, BUTTE COUNTY



A, HENRY J. KAISER COMPANY GRAVEL PLANT SOUTH OF OROVILLE BUTTE COUNTY

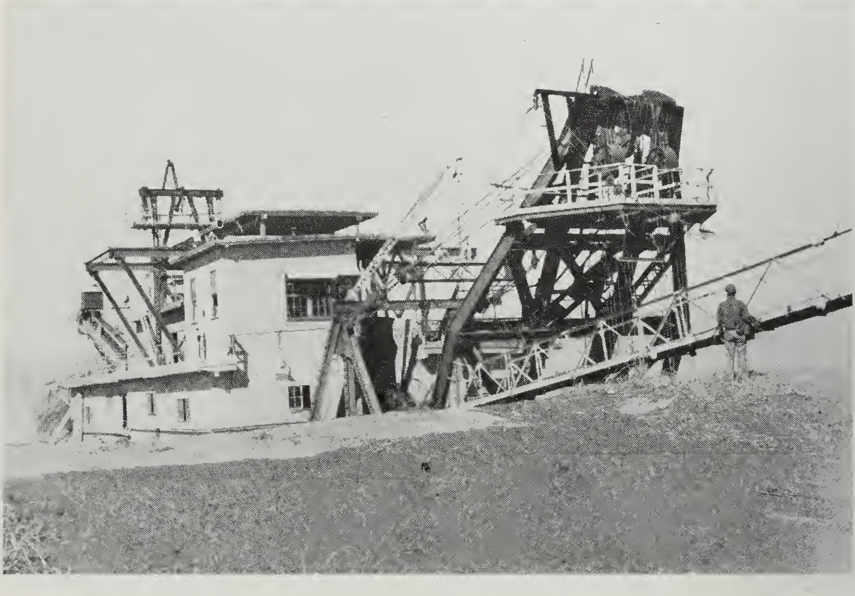


B, LANCHA PLANA GOLD DREDGING COMPANY DREDGE NO. 3, ON BUTTE CREEK EAST OF CHICO, BUTTE COUNTY

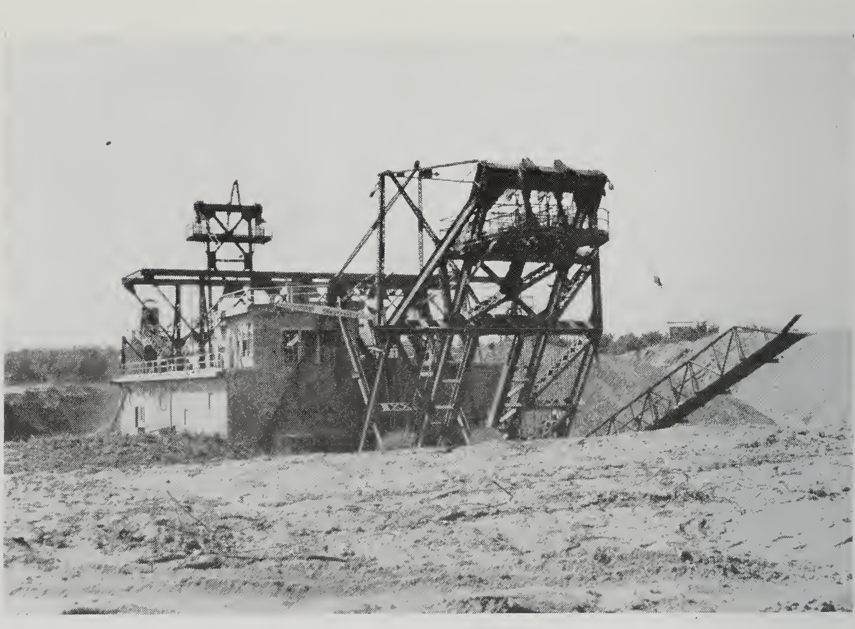


A, SURCEASE (BIG BEND) MILL, BUTTE COUNTY

B, SURCEASE MINE, PLANT YARD



A, YUBA CONSOLIDATED GOLD FIELDS BUCKET-LINE DREDGE NO. 1
OROVILLE DISTRICT, BUTTE COUNTY



B, YUBA CONSOLIDATED GOLD FIELDS DREDGE NO. 3
OROVILLE DISTRICT, BUTTE COUNTY

Asbestos

Small amounts of the amphibole asbestos occur in the northwest-trending serpentine belts in the central and eastern portions of the county. Some tremolite mined from small lenses in serpentine, was produced in the Magalia district by John Quirk of Paradise, in 1947.

Chromite

Chromite has been mined from lenses in serpentine which outcrop in the eastern and central part of the county near Magalia, Pulga, Yankee Hill, Mountain House, and Clipper Mills. During World War II, several carloads of chromite were shipped from the Parks property in sec. 7, T. 21 N., R. 4 E., M. D.[6]

In 1947, a small production was reported by Ray Helmke of Bradley & Ekstrom. It came from a property west of Magalia in sec. 34, T. 23 N., R. 3 E., M. D. A recent map [7] shows seven chromite properties in Butte County. Two of these produced more than 1,000 tons each.

Clay

The clay deposits of Butte County have not been worked in recent years, with the exception of one pit near Oroville, which produced a small amount of pottery clay in 1942.

Brick plants were formerly operated at a clay pit 3.7 miles east of Coxlane spur on the Southern Pacific Railroad between Palermo and Honcut, and at Thermalito. The Thermalito plant used clay from a pit in the SW$\frac{1}{4}$ sec. 22, T. 20 N., R. 3 E., M. D.[8]

Other deposits are described [9] by Dietrich and Aubury.

Coal

Lignite was mined from the C. F. Lott property near Oroville in sec. 12, T. 20 N., R. 3 E., M. D., between 1860-80.[10] It was used in Oroville as a fuel and in the manufacture of gas.

Logan reports [11] that coal occurs in association with the Ione formation, which borders the foothills on the east and northeast sides of the valley. There has been no production in recent years.

Copper-Zinc

Big Bend (Evening Star) mine includes two claims in the SE$\frac{1}{4}$ sec. 8, T. 21 N., R. 5 E., M. D., owned by E. F. Allingham, Rt. 1, Oroville, California. The property was leased in October 1942 by Hoefling Brothers, owners and operators of the nearby Surcease mine.

The ore consists of banded sphalerite, chalcopyrite, and pyrite, and there are streaks of chalcocite, covellite, and tetrahedrite. A little galena and some bornite is found. Gold and silver are associated with the copper minerals. The ore minerals occur as replacements in schist, having been introduced at the expense of sericite and chlorite. The ore bodies were

---

[6] Averill, C. V., California Jour. Mines and Geology, vol. 39, p. 71, 1945.

[7] Jenkins, Olaf P., Economic mineral map no. 3—chromite, scale 1:1,000,000, California Div. Mines, 1942.

[8] Logan, C. A., Butte County: California Div. Mines Rept. 26, pp. 364-367, 1930.

[9] Dietrich, W. F., The clay resources and the ceramic industry of California: California Div. Mines Bull. 99, pp. 64-67, 1938.

Aubury, L. E., The structural and industrial materials of California: California Min. Bur. Bull. 38, p. 211, 1906.

[10] Preston, E. B., Butte County: California Min. Bur. Rept. 11, p. 166, 1893.

[11] Logan, C. A., Butte County: California Div. Mines Rept. 26, p. 367, 1930.

Table 1. Mineral production statistics, Butte County, 1880-1946

Year	Diamonds, value	Gold, value	Mineral water		Platinum		Silver, value	Miscellaneous stone,[1] value	Miscellaneous and unapportioned		
			Gallons	Value	Ounces	Value			Amount	Value	Substance
1880	--------	$430,501	--------	--------	--------	--------	$1,247	--------	--------	--------	
1881	--------	650,000	--------	--------	--------	--------	1,000	--------	--------	--------	
1882	--------	650,000	--------	--------	--------	--------	--------	--------	--------	--------	
1883	--------	630,000	--------	--------	--------	--------	--------	--------	--------	--------	
1884	--------	680,000	--------	--------	--------	--------	--------	--------	--------	--------	
1885	--------	672,569	--------	--------	--------	--------	3,700	--------	--------	--------	
1886	--------	728,160	--------	--------	--------	--------	13	--------	--------	--------	
1887	--------	632,902	--------	--------	--------	--------	6	--------	--------	--------	
1888	--------	550,000	--------	--------	--------	--------	500	--------	--------	--------	
1889	--------	696,628	--------	--------	--------	--------	518	--------	--------	--------	
1890	--------	268,977	--------	--------	--------	--------	5,815	--------	--------	--------	
1891	--------	304,765	--------	--------	--------	--------	229	--------	--------	--------	
1892	--------	316,999	--------	--------	--------	--------	610	--------	--------	--------	
1893	--------	307,351	--------	--------	--------	--------	5,504	--------	--------	--------	
1894	--------	473,673	--------	--------	--------	--------	--------	--------	--------	--------	
1895	--------	697,261	--------	--------	--------	--------	8,936	--------	--------	--------	
1896	--------	749,316	1,900	$775	--------	--------	5,390	--------	--------	--------	
1897	--------	667,025	2,160	900	--------	--------	7,885	--------	700 M	$4,200	Brick.
1898	--------	514,508	2,685	900	--------	--------	9,317	--------	250 M	1,500	Brick.
									150 tons	3,000	Mineral paint.
1899	--------	486,846	2,480	1,240			5,009	--------	300 M	1,800	Brick.
									900 tons	9,900	Mineral paint.
1900	--------	485,589	15,000	1,515	--------	--------	13,082	--------	600 bbls.	600	Lime.
1901	--------	864,978	10,400	1,455	--------	--------	4,634	--------	900 M	7,200	Brick.
									1,500 bbls.	1,500	Lime.
1902	--------	916,782	14,000	1,500	--------	--------	2,219	--------	800 M	5,000	Brick.
									400 bbls.	750	Lime.
1903	--------	1,571,507	13,000	1,550	14	$210	358	--------	1,200 M	7,200	Brick.
									250 bbls.	250	Lime.
									190 tons	250	Limestone.
1904	--------	1,932,552	12,600	1,512	66	1,000	2,302		670 M	4,020	Brick.
1905	--------	2,607,500	15,000	1,500	110	1,770	7,134	--------	400 M	3,200	Brick.
1906	--------	3,016,747	19,500	1,950	26	475	10,853	--------	130 M	1,300	Brick.
1907	--------	2,786,840	21,400	2,140	--------	--------	8,967	--------	--------	--------	
1908	--------	3,139,398	22,450	2,450	--------	--------	12,708	$7,916	--------	--------	
1909	--------	2,987,079	25,400	1,400	--------	--------	7,205	32,140	200 M	1,200	Brick.
									--------	107,170	Unapportioned, 1900-1909.
1910	--------	2,487,791	--------	--------	--------	--------	6,429	34,932	645 lbs.	27	Lead.
1911	$150	2,323,396	--------	--------	--------	--------	5,102	78,208	--------	--------	
1912	--------	2,346,229	--------	--------	--------	--------	5,567	51,879	--------	--------	
1913	175	2,269,849	1,000	250	--------	--------	5,163	258,503	--------	--------	
1914	100	1,700,000	1,200	300	119	381	4,000	50,895	513 lbs.	20	Lead.

1915	300	1,545,976	5,000	850	126	3,997	3,433	67,143	90 lbs.	4	Lead.
									---	540	Chromite.
1916	357	1,257,231	3,150	1,125	76	3,472	3,332	67,892	11 lbs.	2	Copper.
									1,451 tons	13,940	Chromite.
									---	9,576	Other minerals.
1917	125	922,271	3,500	1,450	119	9,106	2,991	89,870	5,746 tons	104,085	Chromite.
									378 lbs.	32	Lead.
									---	329	Copper, manganese, natural gas.
1918	125	645,975	3,900	1,680	114	7,723	2,410	77,822	3,325 tons	134,535	Chromite.
									---	2,765	Manganese and natural gas.
1919	[2]	378,297	6,532	2,388	33	5,071	1,911	92,765	---	1,105	Gems and natural gas.
1920	400	467,900	6,400	5,200	*42	4,714	2,253	[2]	---	161,095	Natural gas and miscellaneous stone.
1921	331	456,760	2,900	4,100	31	2,432	1,759	203,900	---	548	Other minerals.
1922	225	491,201	2,835	2,485	*30	3,826	1,890	220,450	---	548	Other minerals.
1923	---	487,393	3,700	3,300	*19	2,601	1,756	340,250	---	6,648	Other minerals.[3]
1924	---	484,530	6,000	4,500	*20	2,829	2,118	138,000	---	225 9,548	Gems. Other minerals.[4]
1925	---	355,289	4,484	2,742	*56	9,177	4,354	156,738	---	17,878	Other minerals.[5]
1926	175	287,853	---	---	*10	954	2,997	147,604	273 M	4,316	Brick.
									---	18,046	Other minerals.[6]
1927	---	143,494	---	---	---	---	371	---	40 lbs.	5	Copper.
									130 lbs.	8	Lead.
1928	---	48,432	2,190	1,045	---	---	729	556,301	960 M	16,320 17,481	Brick. Other minerals.[7]
1929	[8]550	71,917	---	---	---	---	175	485,187	---	4,108 22,382	Limestone. Other minerals.
1930	25	126,858	[2]	---	[2]	---	422	400,239	353 lbs.	46	Copper.
									---	12,076	Mineral water, natural gas, platinum, soapstone.
1931	250	172,383	[2]	---	[2]	---	650	300,225	2,108 lbs.	192	Copper.
									---	9,037	Brick, mineral water, natural gas, platinum, soapstone.
1932	50	265,589	[2]	---	[2]	---	717	191,487	715 lbs.	45	Copper.
									---	6,624	Lead, mineral water, natural gas, platinum soapstone.
1933	150	296,159	[2]	---	[2]	---	971	98,992	1,133 lbs.	73	Copper.
									---	8,316	Lead, mineral water, natural gas, platinum, soapstone.
1934	150	544,000	[2]	---	[2]	---	3,172	80,971	1,805 lbs.	144	Copper.
									---	9,527	Brick, lead, mineral water, natural gas, soapstone.
1935	60	952,632	[2]	---	[2]	---	4,257	49,653	2,001 lbs.	166	Copper.
									---	3,244	Brick, lead, mineral water, natural gas, soapstone
1936	60	1,202,460	[2]	---	---	---	9,796	174,944	5,008 lbs.	460	Copper.
									---	6,214	Lead, mineral water, natural gas, soapstone.
1937	---	1,558,305	[2]	---	[2]	---	18,354	219,412	2,545 lbs.	308	Copper.
									---	2,613	Lead, mineral water, natural gas, platinum, salt, soapstone.
1938	---	1,882,370	[2]	---	[2]	---	19,669	270,871	---	4,355	Copper, lead, limestone, mineral water, natural gas, platinum, salt, soapstone.

Table 1. Mineral production statistics, Butte County, 1880-1946—Continued

Year	Diamonds, value	Gold, value	Mineral water		Platinum		Silver, value	Miscellaneous stone,[1] value	Miscellaneous and unapportioned		
			Gallons	Value	Ounces	Value			Amount	Value	Substance
1939	----------	$2,079,385	[2]	----------	[2]	----------	$11,611	$123,517	5,838 lbs.	607	Copper.
									11,799 lbs.	555	Lead.
									----------	2,046	Natural gas, mineral water, platinum, salt, soapstone.
1940	----------	2,543,835	[2]	----------	[2]	----------	14,958	159,483	6,349 lbs.	717	Copper.
									----------	3,823	Mineral water, natural gas, platinum, salt, soapstone.
1941	----------	2,981,090	[2]	----------	[2]	----------	21,166	166,947	----------	2,669	Clay, copper, lead, mineral water, natural gas, platinum.
1942	----------	2,132,060	[2]	----------	[2]	----------	14,471	249,337	----------	4,990	Chromite, clay (pottery), copper, lead, mineral water, natural gas, platinum.
1943	----------	525,140	[2]	----------	[2]	----------	5,103	105,281	127,321 lbs.	16,552	Copper.
									15,156 lbs.	1,136	Lead.
									814,458 lbs.	87,961	Zinc.
									----------	14,795	Chromite, mineral water, platinum.
1944	----------	372,225	[2]	----------	[2]	----------	8,416	335,789	464,858 lbs.	62,756	Copper.
									56,209 lbs.	4,497	Lead.
									2,954,519 lbs.	335,789	Zinc.
									----------	9,756	Cadium, chromite, mineral water.
1945	----------	170,800	[2]	----------	[2]	----------	13,587	122,965	404,572 lbs.	54,617	Copper.
									45,321 lbs.	3,898	Lead.
									2,586,024 lbs.	297,393	Zinc.
									----------	350	Other minerals.
1946	----------	768,355	[2]	----------	[2]	----------	1,311	147,534	24,202 lbs.	3,921	Copper.
									67,073 lbs.	8,183	Zinc.
									----------	17,867	Lead, mineral water, natural gas, platinum.
Totals	$3,758	$69,161,883	[2]230,766	$52,202	[2]1,011	$59,738	$332,512	$6,356,042	----------	$1,704,474	

Grand total value ---------- $77,670,609

[1] Includes crushed rock, rubble, rip-rap, sand and gravel.
[2] See under Unapportioned.
[3] Includes diamonds, natural gas, soapstone.
[4] Includes natural gas and soapstone.
[5] Includes brick, copper, gems (diamonds), lead, natural gas, soapstone.
[6] Includes clay (pottery), mineral water, natural gas, soapstone.
[7] Includes copper, gems (diamonds, sapphires), natural gas and soapstone.
[8] Diamonds and precious serpentine.
[9] Includes brick, mineral water, natural gas and soapstone.
* Fine ounces.

roughly lenticular in shape and very irregular in size; average length was about 150 feet, maximum width 40 feet. Ore bodies 6 inches to 40 feet wide were mined. They had an average strike of N. 40° W. and dipped about 80° NE.

The property was developed by an adit level from which a 4- by 6-foot shaft was raised 50 feet to the surface and sunk, on a 70 degree slope, to a depth of 330 feet from the surface. Levels were driven at 50-, 100-, 200-, and 300-foot depths. Drifts extended about 125 feet on each side of the shaft. Vertical raises were run at intervals from the drifts to the level above and the ore was mined by square-set stopes; 8- by 8-inch square timbers were used.

The ore was hauled 5 miles in 3-cubic-yard dump trucks to the Surcease mill which was remodeled to handle the copper-zinc ore. The ore was weighed on 10-ton platform scales before it was dumped into the 100-ton coarse-ore bin. From the ore bin the ore was fed to a vibrating screen by a pan conveyor. The oversize was crushed in a 10- by 24-inch jaw crusher and joined the undersize on a belt conveyor which carried it to a 150-ton fine-ore bin. A variable-drive belt-conveyor fed the fine ore into a 6- by 5-foot ball mill. The ground ore was discharged into a 54-inch duplex classifier. Zinc sulphate and sodium cyanide were added to the sand and it was returned to the ball mill. The overflow from the classifier flowed into a 5- by 4-foot conditioner tank equipped with a 5-horsepower motor which drove the Devereaux blades 300 revolutions per minute. Reagent 404 was added and the pulp was sent to a four-cell Fagergren rougher flotation machine where reagent B23 was added. The rougher copper middling was returned to the circuit. The rougher copper concentrate was sent to a 5- by 5-foot conditioner tank where more zinc sulphate and sodium cyanide were added before it was sent to a 44-inch cell Fagergren cleaner flotation machine. The tailing from this machine was returned to the circuit through the classifier. The copper concentrate was thickened and filtered and sent to the copper concentrate bin. Reagent 208 was added to the tailing from the rougher flotation machine and the tailing was sent to a 5- by 5-foot conditioner tank where copper sulphate was added. The pulp was then delivered to another 5- by 5-foot conditioner tank where lime was added. The conditioned pulp was treated with cresylic acid in a four-cell Fagergren rougher flotation machine. The middling was returned to the flotation circuit. The zinc concentrate was sent to a two-cell Fagergren cleaner flotation machine where calcium oxide and sodium cyanide were added. The concentrate from the cleaner machine was thickened, filtered, and stored for shipment. Sodium cyanide was added to the tailing from the cleaner machine and it was returned to the zinc rougher flotation machine. Reagents B23 and 301 were added to the tailing from the rougher cell and it was sent to a two-cell Fagergren scavenger flotation machine. The tailing from this machine went to waste. The concentrate was returned to the first conditioner tank above the rougher flotation machines. The zinc concentrate was shipped to Kellogg, Idaho, and the copper concentrate was shipped to Tacoma, Washington.

About 30,000 tons of ore containing about 12 percent zinc and 2 percent copper were produced at this property before it was closed down late in 1945. Metal production per man shift underground was about 900 pounds of zinc, copper, and lead.

Allan E. Jones is general manager for Hoefling Brothers, and William E. Messner, general superintendent. Hugh H. Bein was geologist and metallurgist; D. A. Moyer, master mechanic; R. N. Diggles, mill superintendent; J. C. Lawton, mine superintendent; Tom Jones, foreman; and Joe Collie, chemist. The crew averaged about 30 men.

Gems

Californite occurs in the serpentine belt near Pulga.[12] No commercial production is recorded. Several hundred diamonds up to 2 carats in size have been found in the gold-bearing gravel at Cherokee, Morris Ravine, Oroville, Thompsons Flat, and Yankee Hill.[13] They were recovered in the course of washing the gravel for gold.

Gold

Channel (Dally) mine is located in sec. 3, T. 22 N., R. 3 E., M. D., and secs. 25, 26, 35, T. 23 N., R. 3 E., M. D., on land owned by the I. N. Dally estate. It is under lease to the Channel Mining Company of which H. W. Schnell, Post Office Box 1812, Seattle, Washington, is president and general manager. An adit in sec. 3, T. 22 N., R. 3 E., M. D., has been driven in a N. 18° W. direction for about a mile. Seven raises have been run at intervals above the adit in search of the extension of the old Mammoth channel. Raises No. 6 and 7, driven on about a 45 degree slope from the west side of the adit, reached the gravel at about 136 feet. Two men are employed drifting in the gravel from the top of No. 6 raise toward No. 7 raise, a distance of about 500 feet. Raises are driven with a chute and manway compartment and equipped with a single-drum hoist, water, and air lines. The gravel is loaded into mine cars and pulled to the surface by a small storage-battery locomotive. It is dumped through a grizzly, whose rails are spaced 3 inches apart, and into a sluice box 16 inches wide and 36 feet long, fitted with steed-shod Hungarian riffles. The tailing is flushed into Middle Butte Creek through about 60 feet of metal-lined sluice boxes 10 inches wide. Equipment includes a Denver-Gardner single-stage compressor driven by a 50-horsepower motor, and a Denver-Gardner Model 3A drill sharpener. A single track tramline is used to lower timber and supplies down the steep hill from the end of the road. The tramcar is pulled by a single-drum hoist driven by a 2-cycle water power engine built by Williamson Brothers of Philadelphia, Pennsylvania. Two to five men employed by this company have been prospecting the property for about 5 years. There is no record of production from recent operations.

Dailey Chemical Laboratories. Charles, Frank, and George Dailey, Box 228, Oroville, California, operate a plant in Thermalito, a suburb of Oroville, for the recovery of metals from black sands. The black sand is drawn from a metal hopper into a trommel screen 3 feet in diameter and 4 feet long, fitted with a 20-mesh screen. The oversize is run over a copper amalgamation plate 10 by 24 inches in area, and the tailing flows through a trough to waste. The undersize flows into a metal sluice-like pan fitted with diagonal metal riffles. The pan is shaken to collect the heavier minerals in the riffles and permit the lighter sand to flow to waste.

When sufficient concentrate has accumulated, it is dumped into a steel hopper of 1½ tons capacity and fed by an adjustable screw feeder into a ball mill 4 feet in diameter and 18 inches wide, which is driven by a 3-horsepower motor. Certain undisclosed chemicals are added to the charge in the ball mill and the material is ground to minus 100 mesh. The pulp flows over an amalgamation plate 10 by 20 inches in area, from which the sand flows to a shaker pan. The fine platinum and floured quicksilver are caught in the pan and the tailing is run to waste.

---

[12] Logan, C. A., Butte County: California Div. Mines Rept. 26, p. 367, 1930.

[13] Murdoch, Joseph, and Webb, R. W., Minerals of California: California Div. Mines Bull. 136, pp. 129-132, 1948.

An amalgamation unit used to treat small lots of 300 to 400 pounds of black sand consists of a ball mill 3 feet in diameter and 4 feet in length driven by a 2-horsepower motor. About 10 pounds of quicksilver is added in the ball mill and the material is ground to minus 100 mesh. The pulp is washed and agitated in a 3- by 4-foot wooden trough. Amalgam is caught in a trap and the tailing is run to waste.

The plant has a capacity of about $1\frac{1}{2}$ tons of black sand concentrate per day. The Dailey Brothers operate without additional help.

Gold Hill Dredging Company, E. B. DeGolia, president, 311 California Street, San Francisco, California, is operating a bucket-line dredge on the east side of the Feather River in sec. 10, T. 18 N., R. 3 E., M. D., on ground owned by Len Kister. The gravel is 26 to 40 feet deep above a soft volcanic-ash bedrock. There are no large boulders. The dredge is built on a steel barge 110 feet long, 46 feet wide, and 7 feet deep. The digging ladder has seventy-two 9-cubic-foot buckets which are driven by a 200-horsepower motor. The trommel is 8 feet in diameter and 55 feet in length, and has 30 feet of $\frac{1}{4}$-, $\frac{5}{16}$-, and $\frac{3}{8}$-inch holes. Oversize is sent to the tailing pile on a stacker belt, which is 32 inches wide and 115 feet long between pulleys. The spud weighs about 20 tons and is raised by the swing winch which is driven by a 50-horsepower motor through a 6-strand V-belt. The 12-inch diameter Byron-Jackson low-pressure pump is 10 inches in diameter and is driven by a 60-horsepower motor.

The sand passing through the trommel drops into a distributor and is diverted to three sets of two-cell Pan-American rougher jigs on each side of the trommel. The tailing is sent to 12 steel sluice boxes 30 inches wide and 14 feet long, which are fitted with expanded metal over burlap for the first 3 feet, and then with metal-shod Hungarian riffles. Tailing flows to the downstream sluices and into the pond. The rougher jig concentrates flow to a sump, from which they are pumped by either of two Wilfley sand pumps through a 4-inch diameter pipe to a steel hopper above the cleaner jigs. The sand pumps are driven by a 15-horsepower motor. There are two Pan-American type A 24- by 24-inch cleaner jigs driven by water pressure from tanks located on the roof. The concentrate is drawn through steel launders into a hexagonal-shaped clean-up barrel 2 feet in diameter by 4 feet in length. Six copper baffle plates, 5 inches high and 3 feet long, and covered with expanded metal for protection, are mounted on a shaft within the barrel. They are rotated by a chain drive from a $\frac{3}{4}$-horsepower motor. Tailing flows through a 3-inch hose to a ball mill 30 inches in diameter and 4 feet in length, where it is scoured. The ball mill product flows through a steel trough to a second clean-up barrel. The tailing from the clean-up barrel is treated in a two-cell Pan-American scavenger jig. The concentrate is shipped to Loomis. The tailing flows into a steel distributor trough and is diverted to four steel sluice boxes 12 inches wide and 8 feet long, which are fitted with expanded metal over burlap. Quicksilver is caught in traps at the end of the sluices. Tailing flows to the dredge pond.

The dredge has been working in this area since 1938 except for the shutdown during the war. Abe Shaw is dredgemaster and 22 men are employed.

Kelly Hill mine includes 280 acres of patented land in secs. 27 and 28, T. 23 N., R. 3 E., M. D., owned by C. V. Barton, 1122 Kohl Building, San Francisco, California. It is leased to the Magalia Reserve, Limited, M. B. Ellery, Oakland, California, president. Adits have been run into the south slope of the hill in search of an old channel. The Gale adit was driven at an elevation of 1,387 feet in a N. 40° E. direction through black slate for about 1,000 feet, but no gravel was encountered. A second adit whose portal is a short distance southwest of the Gale portal, at an elevation of 1,355 feet, has a bearing of N. 5° W. at the portal; but it has been turned to the right and has a bearing of N. 35° E. at the face, a distance of 50 feet. The property has been idle since 1945. C. E. Wager, superintendent, lives at the property.

Lancha Plana Gold Dredging Company, of which Charles Patmon is president, is operating a bucket-line dredge on Butte Creek, about 6 miles southeast of Chico. The placer land located in sec. 35, T. 22 N., R. 2 E., M. D., is leased from William Bidsworth of Chico. The dredge is built on 18 steel pontoons which make a barge 40 by 70 feet. The bucket line has fifty-seven 4½-cubic-foot buckets. It is driven by a 50-horsepower motor and discharges 24 buckets per minute into a trommel 4 feet in diameter and 24 feet long. The trommel has 18 feet of ⅜-inch diameter holes. It is driven by gears from a 20-horsepower motor. Oversize is delivered to the stock pile by a stacker belt 30 inches wide and 75 feet long. The sand from the trommel is distributed to seven cross sluices and six downstream sluices on each side. The sluices are 30 inches wide and are fitted with rubber-covered wooden riffles. Mercury traps are installed in the distributor channel. Water is supplied by two 8-inch Worthington centrifugal pumps driven by one 60- and one 40-horsepower motor. A 4-inch diameter centrifugal pump is used to prime the larger pumps, for washing decks, and for fire protection.

The spud is 18 by 24 inches in section and 32 feet in length. It is raised by the 50-horsepower winch motor. A D-4 Caterpillar bulldozer and a Wilson 300-ampere arc welder are accessory equipment. Electric power (about 175-horsepower) is obtained from the Pacific Gas and Electric Company lines.

The channel is about 250 feet wide, and the gravel is about 15 feet deep above a hard tuff bedrock. It was tested by churn-drill holes spaced at about 200 yard intervals. There are many 18- to 20-inch boulders and some 36 inches in size.

Ten men are employed under the supervision of Warren Fritter, dredgemaster. The dredge has been in operation at this location since December 1945.

Magalia (Perschbaker) mine is located about 3 miles north of Magalia, California, in secs. 13 and 24, T. 23 N., R. 3 E., M. D. It is owned by the Magalia Mining Company, H. G. Holmes, Magalia, president. Some geophysical prospecting was done in 1945 with a magnetometer, in an effort to map the course of the old Mammoth channel beneath the lava which covers the surface of the claim. Almon E. Smith, a principal stockholder in the company who lives on the property, said that the company had acquired the adjoining Genii property which was last operated in 1933. The Magalia mine has been idle since the Spring of 1947.

Morris Ravine Mining Company, J. H. Sharpe, president, Box 7, Oroville, California, leased its drift mining property located in sec. 29, T. 20 N., R. 4 E., M. D. to the Split Rock Mines, a trust.

Southwest of the old shaft, and at a lower elevation, a new adit is being driven. It was about 700 feet long in a N. 50° E. direction and had been driven through greenstone and some lava rock when visited by the author. It had an 8- by 10-foot cross section and was timbered with sets of 10- by 10-inch square timbers placed close together where the ground was heavy. The revolving bucket-type tunneling machine and the monorail tram which were used to drive most of the adit have been discarded for conventional methods of tunneling. Compressed air was furnished by a Gardner-Denver portable compressor. The adit, near the face, holed into some old workings from an inclined shaft, and a portion of the old channel rim was visible. Rounded white quartz and diorite pebbles imbedded in a grayish-green andesite tuff occurred in a bed about 4 feet thick, between greenstone bedrock and lava and decomposed diabase and tuff roof. Mr. Sharpe estimated that the main channel was about 100 feet ahead. Four men were employed driving the adit.

The milling plant consists of a wood frame and plank ore bin 12 by 12 feet square on top. The gravel is drawn through a gate operated by a rack and pinion into a steel trough 10 inches wide and 15 feet long, which is set on a 12-degree slope. A mercury trap is set in the trough to catch the coarse gold. The material is sluiced and pushed along the trough and into a trommel 42 inches in diameter. Material larger than $\frac{3}{4}$ inch is discarded on a belt-conveyor stacker 20 inches wide and 40 feet long, and delivered to the tailing pile. The stacker is mounted on a steel frame which can be raised or lowered as required. The minus $\frac{3}{4}$-inch material that passes through the trommel flows to two rougher jigs with $\frac{1}{4}$-inch screens. The heavy hutch product is elevated by a hydraulic injector and discharged into a Petersen cleaner jig. The black-sand concentrate from the cleaner jig is ground with mercury in a 30-inch cleanup barrel which is driven by a 3-horsepower motor.

The tailing and oversize from the rougher jigs flow into a steel sluice box 15 inches wide and 20 feet long, which is fitted with Hungarian riffles. A 36-inch length of $\frac{1}{4}$-inch mesh screen at the head of this sluice box discharges the minus $\frac{1}{4}$-inch material into a wooden sluice box 6 inches wide and 15 feet long, which is fitted with expanded metal over burlap. A large tailing pond held by an earth dam settles out the silt. Vernon Petersen is mill foreman. Mr. Sharpe said that the gold from the Morris Ravine Mining Company operation was the size of rice grains and 930 fine. He said that the property has produced over $70,000 and averaged $6.71 per car of material mined. There has been no production from the new adit, and the mill is idle.

The Split Rock Mines organization has been operating the property since December 1, 1946. Henry T. Giller is manager.

Oroville Gold Dredging Company, W. H. W. Wandesford, president and general manager, Oroville, California, operated a bucket-line dredge on the west bank of the Feather River, in sec. 4, T. 18 N., R. 3 E., M. D., in 1941 and part of 1943 and 1944. The dredge was built by the Yuba Manufacturing Company, and it is similar to the other Yuba-built boats operating in the Oroville district, except for some minor changes in the gold-saving tables. It has been idle and in the custody of a watchman since it was shut down in November 1944. The dredge is now owned by the Reconstruction Finance Corporation.

Shawnee (Alladin, McLain) mine is located in sec. 15, T. 24 N., R. 3 E., M. D., on patented land owned by the Diamond Match Company. It is being developed by F. A. Willis who took over the lease from Lou McLain in 1941. McLain operated the property from 1935-41, and mined a segment of the Whiteside channel from an adit driven into the east slope of the hill. He worked a pay width of 60 feet and recovered some coarse nuggets worth as much as $500 each. The course of the channel has not been determined, but it is thought to be N. 70° W. The channel is known to be faulted in places. Willis is prospecting gravel, which he found in a raise 24 feet above the end of an adit driven S. 65° W., for 535 feet. The gravel, about 4 feet thick beneath a lava roof, includes many boulders which must be drilled and blasted. A width of 200 feet has been prospected without finding the pay streak that was mined in the McLain workings farther north. An older adit about 600 feet southeast of the present workings was driven 700 feet in a southwesterly direction, and four raises 22 to 55 feet high were run at 175-foot intervals without finding the channel. The adits were driven through a hard, fine-grained gray rock, probably andesite, and greenstone.

The gravel is loaded into mine cars and trammed by hand to the surface where it is dumped into a wedge-shaped wooden bin. It is drawn from the bin onto a 1-inch wire-mesh screen above a wooden trough 12 inches wide and 10 feet long. The coarse material is washed and discarded to waste. The fines drop about 10 feet into a wooden sluice box 12 inches wide and about 30 feet long. It is fitted with steel-shod Hungarian riffles. Water is obtained from the West Branch of Butte Creek through about a mile of ditch and flume. It is delivered to the mine under a 90-foot head through 900 feet of 8- and 6-inch riveted steel pipe. A 36-inch Pelton water wheel supplies power to drive a Chicago pneumatic air compressor and ventilating fan. The shop tools include a forge, drill sharpener, and drill press. Two men are employed.

Springer Consolidated Mining Company, 51 Clark Street, Brooklyn 2, New York, owns 44.15 acres of patented land in sec. 34, T. 24 N., R. 3 E., M. D. The property was worked by ground sluicing and hydraulicking for many years prior to 1915. It was then equipped for an open-cut, power-shovel operation and mined at the rate of 700 tons per day for 5 months, before it was closed by state and federal agencies early in 1917 for dumping tailing into Butte Creek.

An adit has been driven in a S. 40° E. direction in gray slate for 600 feet. Narrow quartz veins and stringers and associated pyrite, which followed and crossed the slate, were mined where they showed free gold. The quartz was crushed in hand mortars and the gold recovered by panning and amalgamation. The property was last worked under lease by Charles Smith in 1942.

Surcease Mine. The Surcease Mining Company, Box 786, Sacramento, California, owns 1,821.94 acres of patented land in secs. 4, 5, 6, and 7, T. 21 N., R. 5 E., M. D.; secs. 1, 3, and 12, T. 21 N., R. 4 E., M. D.; and sec. 25, T. 22 N., R. 4 E., M D.; all of which were formerly owned by the Goldfield Consolidated Mines and Exploration Company. Hoefling

Brothers of Sacramento purchased the property in 1933. Two quartz-vein systems occur in amphibolite schist on or near the granite contact. One system, including the Surcease vein, strikes N. 30° W. at the southern end but swings to N. 10° W. at the northern end. The width of the veins ranges from 1 to 20 feet. They dip from 20 to 40 degrees east. The better ore seems to occur on the flatter dips.

The second vein system, including the Bunker Hill vein, strikes roughly parallel to the first system and is northeast of it. The Bunker Hill vein is about 4 feet wide between amphibolite schist walls and dips 55 to 70 degrees east.

The Surcease vein is developed by a two-compartment shaft, 1,100 feet deep on a 40-degree slope. The hoist is underground on the 210-foot adit level and the shaft is caved above this level. Other levels are at 300, 400, 600, 775, 950, and 1,100 feet. The principal ore bodies were northwest of the shaft and extended a maximum of 2,000 feet on the 775-foot level. Most of the ore was found in a fault zone that strikes N. 70° E. and dips 65° to 70° N. The faulting cut all the important veins but displaced them very little. The north boundary of the fault zone is about 1,400 feet northwest of the shaft on the 775-foot level, and the principal ore bodies were stoped between the 775- and 950-foot levels. Some gold-bearing quartz was developed 600 feet north of the fault on the 775-foot level. The vein is 5 feet wide on the 1,100-foot level.

Raises 8 to 12 feet in width were run in ore from level to level, and timbered with stulls. Stoping was started at the top; ore was mined downward for a width of 50 feet on each side of the raises. Stulls and pillars of low-grade portions of the vein were used to support the back. Mucking was done with double-drum air hoists and scrapers. Ore was scraped directly into mine cars. Lenses were connected, and irregular in size. There was a marked difference in the grade of the ore; the quartz for the most part either containing more than 0.2 or less than 0.06 of an ounce of gold per ton. Concentration was fairly consistent within lenses. A small diamond drill was used to prospect the lenses.

The Bunker Hill vein was developed by an inclined shaft located 2,000 feet north of the Surcease shaft. The shaft, sloping 55 degrees in a northeasterly direction, is 700 feet deep; there are levels at 100, 200, and 300 feet. An adit was driven to the shaft at the 300-foot level. The 4-foot quartz vein in amphibolite schist was stoped to the surface at approximately 1,000 feet north of the shaft. About 30,000 tons of ore was mined above the adit level before the mine was shut down by War Production Board Order L-208, in October 1942. The adit and shaft have since caved.

The gold was associated with pyrite, chalcopyrite, marcasite, and galena. In addition, the oxidized ores carried some limonite, covellite, bornite, pyrrhotite, native antimony, and bournonite.

The ore was crushed in a 10- by 24-inch jaw crusher and ground to a size between 35 and 48 mesh in a 6- by 5-foot ball mill. The free gold was recovered in jigs, and by tabling and amalgamation. The tailing from the table and sand from the 5- by 20-foot duplex classifier which treated the jig tailing were returned to the ball mill. The overflow from the classifier was sent to five Fagergren flotation cells. Flotation concentrate (2½ tons per day) was reground to minus 325 mesh in a 3- by 8-foot ball mill and agitated in a cyanide solution in two 8- by 8-foot agitators.

The pulp was then sent to a 6-foot hydro-separator from which the sand was pumped back to the ball mill and the slime was sent to two more 8- by 8-foot agitators. Gold was precipitated from the cyanide solution with zinc dust by the Merrill-Crowe process.

The tailing from the flotation cells was sent to a 39-inch duplex classifier from which the overflow was thickened and filtered and the tailing sent to waste. The sand was leached in five 50-ton capacity leaching tanks. Gold was precipitated from the cyanide solution with zinc dust by the Merrill-Crowe process. In 1940, the milling costs plus tailing loss was $2.77 per ton for some 23,000 tons processed. The mine produced 30,000 tons of ore in 1942 before it was closed. The staff included W. E. Messner, mill superintendent; Kevin Malone, mine superintendent; Milo Horner, master mechanic; and Jack Warren, accountant. Allan E. Jones was general manager.

Wyoming (Black Diamond) mine includes 34 acres of land in the NE¼ sec. 34, T. 24 N., R. 3 E., M. D., owned by E. N. and Mattye M. Understock of Magalia, California. The old adit, which was driven S. 55° W. for about 2,000 feet and from which about 1,000 feet of drifts and raises were run, has been abandoned. A new adit is being driven from a location 90 feet higher and several hundred feet southwest. The first 200 feet of the new adit was driven in a S. 65° W. direction through a spongy brown limonite-stained quartz formation which shows schistosity and includes many thin seams of quartz and green copper minerals across as well as parallel to the schistosity. In the next 200 feet the adit was driven in a S. 70° W. direction through shale. It is being driven in search of quartz veins and stringers rich in gold where they cross the black slate formation. The property is equipped with a single-stage air compressor, rock drills, mine cars, and accessory small tools. It is being developed by the owner.

Yuba Consolidated Gold Fields, 351 California Street, San Francisco, California, is operating its Yuba-built Biggs dredge No. 1 in sec. 15, T. 18 N., R. 3 E., M. D., on land owned by Virginia Hixon. The dredge has 84 buckets of 7½ cubic yards capacity and is similar in design and construction to Yuba dredge No. 3, except for some minor changes in the gold-saving tables. The gravel is 18 to 50 feet deep above a soft volcanic-ash bedrock. The top soil is about 12 feet deep and there are no large boulders. The dredge has been operating in this area since 1935, except during the war period. John S. Falk is dredgemaster and 11 to 13 men are employed.

Yuba Consolidated Gold Fields operated its Yuba No. 2 dredge in sec. 15, T. 18 N., R. 3 E., M. D., until it capsized in 1942. It was similar in design and construction to the other Yuba-built boats operating in this district. It has been dismantled except for the steel hull, and the remaining ground will probably be dredged by Yuba dredge No. 3.

Yuba Consolidated Gold Fields, 351 California Street, San Francisco, is operating its Yuba dredge No. 3 in sec. 15, T. 18 N., R. 3 E., M. D., on land leased from Sarah V. Hixon. The gravel is 48 feet deep above a soft clay bedrock. The top soil is about 15 feet deep.

The dredge is built on a steel hull 54 feet wide, 144 feet long, and 8½ feet deep. The digging ladder has 84 buckets of 7½ cubic feet capacity. They are rotated by a 200-horsepower motor through a V belt. Twenty-four buckets are discharged per minute into a trommel 7 feet in diameter and 40 feet long which is driven by a 50-horsepower motor. The screen is 30 feet long and has 5/16- to ½-inch perforations. Oversize flows to the tailing stacker belt which is 34 inches wide and 139 feet long between pulleys. The sand is distributed to a bank of nine double-deck cross sluices 32 inches wide and 12 feet long situated on each side of the trommel. The cross sluices discharge into longitudinal sluices that have slots cut in the bottom through which some of the sand drops into a second bank of nine double-deck sluices. At the end of the longitudinal sluice the sand discharges into a bank of three double-deck sluices. All sands finally flow into a downstream sluice 30 inches wide and about 80 feet long and are discharged into the pond. The sluices are fitted with Hungarian riffles and mercury traps are used in the top sections. The spud weighs about 23 tons, and it is raised by the swing winch which is driven by a 60-horsepower motor.

The Yuba-built 10-inch diameter centrifugal high-pressure pump is driven by a 100-horsepower motor. There are two 10-inch diameter low-pressure pumps driven by 75-horsepower motors.

The ground has been tested with holes drilled with Keystone drills and spaced 400 to 800 feet apart. A strip about 350 feet wide is being dredged. There are no large boulders and the dredge handles an average of 470 cubic yards per hour. The gold is fine and is cleaned up once a week. Black sands are not saved.

The dredge has been operating in this area since 1940 but was shut down during the war. Operations were resumed in April 1946. C. D. Brophy is dredgemaster and 14 men are employed.

Lead-Silver

The lead and silver produced in Butte County in recent years came as a by-product from the copper-zinc ores of the *Big Bend (Evening Star) mine* in sec. 8, T. 21 N., R. 5 E., M. D. This property was leased and operated by Hoefling Brothers from 1942-45. It has already been described as a copper mine in this report.

Bonanza King prospect is in sec. 16, T. 25 N., R. 5 E., M. D., at an elevation of 6,000 feet. It has not been operated in recent years. An earier report states: [14]

> "A shipment of 2,230 pounds in 1924 gave 0.57 ounce of gold, 112.58 ounces of silver, 4.65 percent copper, 53.4 percent silica, 1.8 percent iron, and 2.6 percent alumina (Kennett smelter). Another lot of 1,720 pounds, shipped in November 1927, carried 0.71 ounce of gold, 96.65 ounces of silver, 8 percent lead, 3.4 percent copper, 6.4 percent zinc, 2.1 percent antimony, 0.1 percent arsenic, 2.7 percent iron, 61.6 percent insoluble. After all charges and deductions, the net return on the latter lot was $39.68 (Selby smelter). Sterling City, the nearest railroad point is 20 miles distant."

The prospect was developed by a shaft 24 feet deep, and the ore was sorted from a streak 16 inches wide which was included in a wider vein.

Limestone

Deposits of limestone and marble which occur in the eastern half of Butte County have not been worked in recent years. They were described by Logan.[15]

---

[14] Logan, C. A., Butte County: California Div. Mines Rept. 26, p. 409, 1930.

[15] Logan, C. A., Limestone in California: California Jour. Mines and Geology, vol. 43, pp. 175-357, map, 1947.

Manganese

The manganese deposits in Butte County were idle when the survey was made for this report and the following information is taken from an earlier publication.[16]

> "Ten manganese deposits are known to occur in Butte County. All but two of these are situated in the eastern tip of the county, near Clipper Mills. The Josephine prospect lies in the center of the county, near Yankee Hill, and the Smithwick and Noble property is located in the northern part of the county, near Butte Meadows. Past production from the county amounts to 305 tons.
>
> "The manganese in Butte County is found in fine-grained quartzite, interbedded with dark slate, phyllite, and sericite schist. The quartzite looks very much like metamorphosed chert, and in some deposits, such as the Binet, it alternates with slate in such a way that recalls the rhythmic bedding of the Franciscan chert. Most of the deposits in Butte County are low grade and consist of thin veins of oxide or of oxide disseminated in chert, but the ore body at the Bear Canyon mine has a maximum thickness of 4 feet. The primary mineral is probably rhodonite."

Mineral Paint

A deposit of ocher in secs. 5 and 6, T. 23 N., R. 4 E., M. D., near the Doon road and a mile from the Southern Pacific Railroad has been developed by an open cut and an adit 200 feet long. There was a small production from the deposit in 1898-99.[17]

The Ochre No. 1 and *Ochre No. 3 claims* include 36 acres of patented land in sec. 6, T. 23 N., R. 4 E., M. D., owned by Dora M. and LeRoy E. Black of Chula Vista, California. There has been no production of ocher in Butte County in recent years.

Mineral Springs

Richardson Springs are located in Mud Creek Canyon in sec. 17, T. 23 N., R. 2 E., M. D., about nine miles northeast of Chico, California. Five saline-sulphur springs have been developed and a popular health resort with a modern hotel and cottages has been built to accommodate the many people who go there to drink and bathe in the medicinal waters. The water is also bottled for sale and medicinal salts are produced by evaporation. Natural gas rises from one well, and it is collected and used at the hotel.

Natural Gas

Natural gas rises from one of the springs at Richardson Springs in sec. 17, T. 23 N., R. 2 E., M. D. It is collected and used at the hotel.

Platinum-Group Metals

The platinum group metals have been produced with the placer gold recovered by dredging and drift mining. Also, a small amount has been produced from the surface placers and river bars on the upper course of Feather River. Logan [18] stated that the platinum metals recovered by the dredgers occurred in small, thin flakes carrying 68 to 72 percent platinum and about 20 percent osmiridium.

Soapstone

Soapstone has been mined from patented land in sec. 32, T. 22 N., R. 5 E., M. D., owned by Anna Grant McLean of San Francisco. It was shipped to the bay area and used for roofing granules. There has been no production recorded since 1940.

---

[16] Jenkins, O. P., and others, Manganese in California: California Div. Mines Bull. 125, pp. 75, 104-105, 1943.

[17] Logan, C. A., Butte County: California Div. Mines Rept. 26, p. 408, 1930.

[18] Logan, C. A., Butte County: California Div. Mines Rept. 26, pp. 408-409, 1930.

Stone (Miscellaneous)

Butte County Gravel Plant. Butte County is operating a gravel plant on old dredge tailing in sec. 15, T. 18 N., R. 3 E., M. D., on land owned by Carleton Grubbs. The cobbles and gravel are stacked 18 to 20 feet above the dredge sand, and they are pushed into a wooden hopper with a Caterpillar D-8 bulldozer. The material is drawn from a gate at the bottom of the hopper and processed in an Austin-Western No. 101 crushing and screening unit.

A belt conveyor 30 inches wide discharges the material onto a vibrating screen which separates it into plus 2-inch, minus 2-inch to plus 1¼-inch, and plus 1-inch sizes. The plus 2-inch size is crushed to minus ¾-inch in an 18- by 20-inch jaw crusher. The minus 2-inch and plus 1-inch material is crushed to minus ¾-inch size in a set of 30-inch diameter rolls. The minus ¾-inch product from the jaw crusher and rolls is stock piled. Power is obtained from a Caterpillar D-13,000 engine. About 350 cubic yards of gravel is processed per day. It is all used for road gravel. The heavy manganese-steel jaws for the jaw crusher are lifted by a P & H dragline. They are used six days and turned over once. They crush 4,500 to 5,000 cubic yards before they are worn out. Five men are employed under the supervision of Willard Webster.

Butte Creek (Johnston) Rock Company is on the west side of Butte Creek about 3 miles east of Chico in secs. 4 and 5, T. 21 N., R. 2 E., M. D. The property was purchased from the Johnston Rock Company in September 1946 by Gilbert Alm, Post Office Box 512, Chico, California. Dredge tailing along Butte Creek is loaded into 5- or 6-cubic-yard dump trucks by a Northwest dragline equipped with a 1¼-cubic-yard bucket. The gravel is about 18 feet deep above the sand in the tailing-pile. The trucks are discharged into a concrete hopper through a rail grizzly that has rails spaced 11 inches apart. The gravel is drawn from the hopper nto a belt conveyor 32 inches wide and 250 feet long, and is discharged about 40 feet higher over a manganese-steel bar grizzly. Material over 3 inches in size slides to a 20- by 36-inch jaw crusher set to crush to 2½ inches. The jaw crusher is driven by a 100-horsepower electric motor. Material under 3 inches in size drops to a screen trommel 42 inches in diameter and 16 feet long. The trommel produces three sizes: 2½ to 1½ inch; 1½ to ¼ inch; and minus ¼ inch. The sand and gravel are washed in spiral classifier-type washers. The sand is delivered to a stock pile by a belt conveyor. The gravel is discharged onto a conveyor belt and delivered to a 3- by 6-foot shaking screen fitted with a ¾-inch mesh screen. The oversize (1½- to ¾-inch material) is delivered to the stock pile by a conveyor belt 20 inches wide and 150 feet long. Undersize is delivered to the concrete sand stock pile by a conveyor belt 20 inches wide and 200 feet long.

The concrete aggregate material stock pile is above a tunnel 7 feet in diameter built of corrugated iron segments. It is divided into three compartments for storing the following size materials: 1½- to ¾-inch; ¾- to ¼-inch; and minus ¼-inch, or sand. Each compartment has five steel arc gates from which the desired material can be drawn onto a conveyor belt 24 inches wide and 150 feet long. The belt discharges into a steel bin which is divided into three 20-cubic-yard compartments, and one 60-cubic-yard compartment. Railroad cars or trucks can be loaded from these bins. Trucks are weighed on a Fairbanks Morse platform scale of 48,000 pounds capacity.

The 2½- to 1½-inch material from the trommel is dropped onto a conveyor belt 24 inches wide and 78 feet long and is delivered to a gyratory crusher which is 3 feet in diameter and set to crush to ½-inch. Rocks from 3½- to 2½-inches in size are crushed in a gyratory crusher which is 4 feet in diameter and driven by a 150-horsepower motor. It is set to crush to minus 1 inch. Cobbles 3½ to 11 inches in size are crushed to minus 2½ inches in the 20- by 36-inch jaw crusher, and delivered by belt conveyor to the 4-foot diameter gyratory crusher. Material from both gyratory crushers slides to a belt conveyor 24 inches wide and 112 feet long and is discharged onto a 4- by 8-foot vibrating screen. All the material minus ⅛-inch in size is classified as dust, and it is dropped on a belt conveyor 30 inches wide by 80 feet long and delivered to the hot asphalt material stock pile. The material over ⅛-inch in size slides to a belt conveyor 24 inches wide and 140 feet long and is delivered to a 4- by 8-foot triple-deck vibrating screen which is located above concrete silo-type bins. The 1½- and ¾-inch sizes are delivered directly to the silo bins. The minus ¾-inch size drops to a belt conveyor 24 inches wide and 34 feet long and is delivered to a 4- by 8-foot triple-deck vibrating screen fitted with ¾-, ½-, and ¼-inch screens. All material is washed by sprays on both vibrating screens before it is sent to the silo bins. There are eight concrete silo bins 22 feet in diameter and 50 feet high. They have steel gates from which the desired size material can be drawn onto a conveyor belt 24 inches wide and 120 feet long which runs between the two rows of bins. Either railroad cars or trucks can be loaded from the belt conveyor. The plant has a capacity of 600 cubic yards in 8 hours. Deliveries are made with 12 dump trucks.

The Standard hot mix plant mixes minus ½-inch material in 3,000-pound batches and has a capacity of 1,000 tons in 8 hours. Ed Bordin is superintendent at the plant and 30 men are employed.

Central Sand and Gravel plant, in the bed of Dry Creek in sec. 13, T. 20 N., R. 2 E., M. D., is on land owned by Charles Bonham. The sand and gravel are dug from a cut about 50 feet wide, 1,200 feet long, and 4 feet deep. The cut is refilled each year in the rainy season when tailing from the old Cherokee hydraulic mine is flushed into it. This area is sometimes under 4 feet of water.

The sand and gravel are dug with a General Excavator dragline equipped with a 30-foot boom and a ¾-cubic-yard bucket. The material is first stock piled on the bank to dry and then loaded on a White dump truck and hauled to the screening plant. The trucks dump the material into a steel hopper from which it is drawn onto an inclined conveyor belt 20 inches wide and 100 feet long. The belt discharges onto a Lippman shaking screen which is driven by a 7½-horsepower motor and fitted with ¾-, ½-, and ⅛-inch mesh screens. Material over ¾-inch size slides through a steel pipe to a stock pile and is used to build roads. The minus ⅛-inch material flows through a steel pipe 8 inches in diameter and goes directly to a concrete sand stock pile, or it can be diverted to flow into a spiral classifier-type washer which is chain driven from a 7½-horsepower motor. All of the material is washed on the screen with a spray. The sand that goes through the spiral washer is clean enough to be classed as plaster sand. Wash water is pumped through a 4-inch diameter pipe by a Deming centrifugal pump driven by a 20-horsepower motor. There are two steel cylindrical storage bins 8 feet in diameter and 12 feet deep, and one steel rectangular bin 8 by 8 feet in area and 12 feet deep. A fourth steel bin, 8 by 8 by 8 feet is not being used. The various screen products flow into these bins and are drawn into trucks through steel arc gates set in the bottom. Truck loads are weighed on a L. R. Murphy Company 30-ton platform scale. The plant is owned and operated by A. W. Mastello and Son of Oroville, California. One man is employed at the plant.

Henry J. Kaiser Company, Kaiser Building, Oakland, California, owns 500 acres of land in secs. 25, 35, and 36, T. 18 N., R. 3 E., M. D., on which there are tailing piles of cobbles and gravel left from former gold-dredging operations. The rock and gravel is 18 to 22 feet deep above the sand. It is loaded into Western side-dump cars of 12 cubic yards capacity with a Bucyrus Model 50-D shovel equipped with a 2½-cubic-yard bucket. The shovel is mounted on Caterpillar treads and the cars run on standard-gauge railroad track which can be shifted along the bank as the pit enlarges. Trains of five cars are pulled to the crushing and screening plant by two Porter steam locomotives.

The cars are unloaded through a steel-rail grizzly with rails spaced at 12 inches. The oversize is broken by hand with sledges. The undersize drops to a hopper from which it is drawn by a Bodinson feeder onto a belt conveyor 32 inches wide and 250 feet long and delivered to a trommel 5 feet in diameter and 20 feet long. Material under 1½-inches in size drops onto a conveyor belt 24 inches wide and 300 feet long and is sent to a stock pile. Rocks 1½ to 3 inches in size are delivered to a Symons cone crusher 4 feet in diameter, driven by a 100-horsepower motor. Rocks over 3 inches in size are passed to a Symons cone crusher 7 feet in diameter which is driven by a 200-horsepower motor. The crushed rock from both cone crushers is from 2½ inches to dust in size. It slides to a conveyor belt 30 inches wide and 150 feet long and is discharged onto one single-deck and two Symons double-deck shaking screens. The screens produce a ¾- to 2½-inch material which is used for railroad ballast, and minus ¾-inch material which is used for roads.

The minus 1½-inch material that is on the stock pile is loaded into railroad cars with a railroad crane using a clamshell bucket, and returned to the crushing plant. It is screened to yield ¾- to 1½-inch, and ¼- to ¾-inch sizes. The sands are not saved. Water sprays wash the material on the screens.

Stanley S. Lord is superintendent at the plant and a crew of 14 men work 6 days a week. About 150,000 tons of material is processed in a year.

Kemen Gravel Pit. J. C. Kemen of Paradise, California, operates a rock-crushing plant on old mine tailing in sec. 24, T. 23 N., R. 3 E., M. D., which he has leased from H. G. Holmes of Magalia. The material is pushed into a hopper with a Caterpillar 60 bulldozer and drops into a jaw crusher set to crush to 1 inch. The crushed material is raised about 20 feet and discharged into a wooden storage bin. Trucks are loaded from the gates beneath the bin. The crushed material is used for concrete aggregate and for roads and driveways. Two men are employed.

Kennedy Gravel Pit, west of the county road in secs. 18 and 19, T. 22 N., R. 3 E., M. D., is owned and operated by J. J. Kennedy of Chico, California, via Nimshew stage. The sand from a former dredging operation is separate from the gravel and is about 8 feet deep in the pit above a brown clay bedrock. The sand contains sufficient clay to make a desirable road mix. The material is pushed from the pit with a Caterpillar 30 bulldozer. Trucks are loaded beneath a ramp. Kennedy works alone and digs from 20 to 30 cubic yards per day.

Billie Martin of Chico loads gravel from a dry creek bed just south of the highway in sec. 7, T. 20 N., R. 3 E., M. D. A Model 30 P & H dragline equipped with a ¾-cubic-yard bucket is used to load dump trucks. Gravel is advertised for sale at 50 cents a cubic yard. The dragline was idle when the property was visited.

Roy Mathews Sand, Gravel, and Dirt Company is operated by Roy Mathews, Route 1, Box 275 E, Gridley, California. Gravel is loaded from a bar on the south bank of the Feather River in sec. 33, T. 18 N., R. 3 E., M. D. A P & H dragline with a 30-foot boom and a ⅝-cubic-yard bucket is used to load four 5-cubic-yard dump trucks. The gravel is hauled about 1½ miles west on the Oroville-Gridley road to a screening plant. It is dumped into a hopper through a rail grizzly with rails spaced 6 inches apart, raised with a bucket elevator, and discharged onto a 4- by 10-foot Symons shaking screen which is driven by a 3-horsepower motor. Material between 1½ and ¾ inches in size drops into a steel bin of 15 cubic yards capacity and the minus ⅜-inch material classed as sand drops into a similar bin. The rock larger than 1½ inches in size is stored in a third bin from which it is hauled to a stock pile. A 12- by 16-inch jaw crusher driven by a 20-horsepower motor can be used to crush the material larger than 1½ inches in size if more gravel is needed.

Gravel and sand are drawn from the bins into hoppers and weighed by a Kron scale. The desired amount of each material is discharged onto a conveyor belt and cement is added from a hopper located above the belt. The conveyor belt discharges into Ready-Mix concrete trucks of 4 cubic yards capacity. Water is measured into a tank on the truck.

The plant can deliver about 60 cubic yards of concrete and 150 cubic yards of road gravel per day within a 15-mile radius. It has been in operation at this location since 1945. Six men are employed.

Sake and Sanders Rock Pit. Bill Sake and Ed Sanders are mining serpentine from a pit near Magalia in sec. 25, T. 23 N., R. 3 E., M. D. The rock is broken by drilling toe holes 4 to 6 feet deep in the pit with a jackhammer, and loading them with six or seven sticks of powder. The rock is loose, so only a few holes are blasted each week. The pit is about 125 feet long, 30 feet wide, and 20 feet deep. The loose and broken rock is pushed with a Caterpillar 30 bulldozer to a steel hopper. The rock is drawn from the hopper into a gyratory crusher 24 inches in diameter which is belt driven by a four-cylinder Sterling gasoline engine. The material is crushed to 1¾ inches and drops into an elevator boot. A bucket elevator having 83 buckets 6 by 6 by 12 inches in size raises the crushed rock about 15 feet and discharges it into a wooden bin of 16 cubic yards capacity. Trucks are loaded beneath the bin through a cone-shaped gate set in the floor of the bin. About 100 cubic yards of the material is mined per day. It is used for roads and driveways. Two men are employed.

Stearns Sand and Gravel Company. Claude Stearns of Chico, California, is operating a gravel pit on Dry Creek just east of the Chico-Oroville highway in sec. 8, T. 20 N., R. 3 E., M. D. It consists of tailing from the old Cherokee hydraulic mine that is flushed into the creek during the rainy season. The gravel is dug to a depth of 4 to 5 feet with a Byers dragline equipped with a 30-foot boom and a ½-cubic-yard capacity bucket.

A Barber-Green No. 35 loader is also used to excavate; it lifts pit material about 9 feet high, and discharges it onto a 3- by 7-foot shaking screen fitted with ¼-inch mesh screen. The minus ¼-inch material is classed as sand, and it slides directly into trucks for delivery. The oversize is discarded. The Barber-Green unit has a capacity of 1 cubic yard per minute. It is powered by a Hercules 20-horsepower gasoline engine. Material is loaded into International dump trucks of 5 cubic yards capacity. From 50 to 60 cubic-yards of pit run gravel are dug per day.

L. L. Ultican, Post Office Box 1202, Chico, California, is operating a gravel screening and ready-mix concrete plant on Highway 99E south of Chico, in sec. 36, T. 20 N., R. 3 E., M. D. The gravel is purchased from various pits in the district and delivered to the plant where it is dumped through a rail grizzly with 4-inch spaces and into a steel bin of 20 cubic yards capacity. The minus 4-inch material is drawn from the bin onto an inclined belt conveyor 24 inches wide and 120 feet long, and is discharged over a triple-deck vibrating screen which is driven by a 7½-horsepower motor. Material minus 1½, ¾, and ⅜ inches in size is diverted to three steel bins of 50, 30, and 30 cubic yards capacity, respectively.The desired amounts of the various materials is weighed into Transit-Mix trucks of 2½ and 3 cubic yards capacity. From six to ten men are employed and deliveries are made within a 30-mile radius.

Tabulated list of mines and prospects, Butte County, California

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references*
			Sec.	T.	R.	B&M		
	Alvarado placer	H. J. Anderson, c/o Alma Lockie, Rt. 1, Box 162A, Paradise, Calif.	SE¼ 34	24N	3E	M.D.	Gold	114.4 acres patented in Sterling City district. Idle, 1948.
	American placer	Lewis Venas and W. J. and I. Rankin, Sterling City, Calif.	W½ SW¼ SE¼ 20	25N	5E	M.D.	Gold	Patented. Idle, 1948.
7	Bader Brothers	E. F. Woodworth, Paradise, Calif., lessee, in 1930	SE¼ 36	23N	3E	M.D.	Gold	160 acres. Idle, 1948. R. 26, p. 385.
8	Banner	Roy D. and Jennie Livesly, Oroville, Calif. (1932)	NW¼ 34	20N	4E	M.D.	Gold	R. 11, p. 153; R. 13, p. 82; R. 15, pp. 211-212; R. 26, pp. 369-370.
9	Berry Creek	Carl Johnson, Oroville, Calif. (1930)	E½ E½ 28	21N	5E	M.D.	Gold	R. 26, p. 370; R. 31, p. 6. 80 acres.
6	Big Bend (Evening Star)	E. F. Allingham, Rt. 1, Oroville, Calif.	SE¼ 8	21N	5E	M.D.	Copper and Zinc	Leased and operated by Hoefling Brothers, 1820 D Street, Sacramento, Calif., R. 24, p. 181; R. 26, pp. 367, 372-373; R. 39, p. 312.
	Big Joe	Oscar J. and Mabel I. Kobes, 1623 Bird St., Oroville, Calif.	SE¼ NW¼ 20	23N	4E	M.D.	Gold	Patented land in the Concaw district. Idle.
10	Bingstresser	Mary M. and Wallace Densmore, c/o C. F. Aaron, Box 47, Marysville, Calif.	SE¼ NE¼ Lot 43 12	20N	7E	M.D.	Gold	Clipper Mills district. Patented. Idle in 1948.
11	Bloomer Hill	J. F. Garrette, Woodland, Calif. (1930)	NE¼ 35	21N	4E	M.D.	Gold	162 acres. Idle, 1948. R. 26, pp. 370-371.
	Bloomington	Clem G. Perkins and Ruby I. Martin, 165 Farralane St., San Francisco, Calif.	Lot 43 in SE¼ 9	20N	4E	M.D.	Gold	19.81 acres patented in the Cherokee district.

---

* References are to bulletins and reports and registers of mines of the California State Division of Mines, with the exception of Water-Supply Paper 238, issued by the U. S. Geological Survey.

12	Blue Hog	Feather River Land & Mining Company, c/o Joseph Coyne, 510 S. Spring St., Los Angeles, Calif. (1930)	SE¼ 19, NE¼ 30	22N	4E	M.D.	Gold	R. 15, p. 200; R. 17, p. 416; R. 18, p. 258; R. 24, p. 194; R. 26, pp. 386-387.
74	Bonanza King	John Wells, Yankee Hill, Calif. (1930)	16	25N	5E	M.D.	Lead	R. 24, p. 209; R. 26, p. 401.
	Boston Quartz	Edyth Dungan and A. O. Ford, P.O. Box 336, Pacific Grove, Calif.	NE¼ 9	20N	4E	M.D.	Gold	9.5 acres patented in the Cherokee district.
	Burtz Placer Mining Company	G. W. Lambert, Jr., Taylorsville, Calif.	NW¼ 2	22N	3E	M.D.	Gold	125 acres patented in the Magalia district.
77	Butte County Gravel Plant	Property is owned by Carleton Grubbs, Oroville, Calif.	15	18N	3E	M.D.	Sand and gravel	Old dredge tailing.
78	Butte Creek (Johnston) Rock Company	Gilbert Alm, P.O. Box 512, Chico, Calif.	4, 5	21N	2E	M.D.	Sand and gravel	Old dredge tailing., R. 24, p. 210; R. 26, pp. 410-411.
13	Carlisle	Wm. Denman, San Francisco, Calif., and the heirs of Mrs. Rose Hazelton	35	20N	6E	M.D.	Gold	600 acres patented and 40 acres unpatented. R. 26, pp. 371-372.
	Central	F. M., G. N. and W. K. Sparks, 1655 Robinson St., Oroville, Calif.	Lot 55 in SE¼ 29, NE¼ 32	20N	4E	M.D.	Gold	47 acres patented in the Morris Ravine district.
79	Central Sand & Gravel Plant	Charles Bonham, Oroville, Calif.	13	20N	2E	M.D.	Sand and gravel	The plant is owned and operated by A. W. Mastello & Son, Oroville, Calif.
14	Channel (Dally, Mammoth Magalia)	I. N. Dally estate	W½ 25, 26, N½ N½, S½ NW¼ 35, 3	23N 22N	3E 3E	M.D. M.D.	Gold	R. 26, p. 400; R. 31, p. 5. Leased and operated by Channel Mining Company, H. W. Schnell, president, P.O. Box 1812, Seattle, Wash.
15	Cherokee Flat Blue Gravel	Dr. Frank M. Cannon, Point Reyes Station, Calif.	SW¼ SW¼ 33	21N	4E	M.D.	Gold	112 acres patented in the Cherokee district. R. 6, pt. 2, pp. 24, 25; R. 10, p. 124; R. 11, p. 155; R. 13, pp. 92-93; R. 18, pp. 258-259; R. 26, pp. 387-389.

Tabulated list of mines and prospects, Butte County, California—Continued

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B&M		
	Church Lode	F. J. Ster, 3801 San Pablo Ave., Emeryville, Calif.	Lots 47, 48, 49, 50, SE¼ 2, NE¼ 11	19N	6E	M.D.		Patented land in the Forbestown district.
16	Contention placer	P. J. McHugh, Star Rt., Magalia, Calif.	Lot 4 SW¼ 36	24N	3E	M.D.	Gold	1.62 acres patented land in the Sterling City district. R. 13, 1.84; R. 13, p. 84; R. 15, p. 200.
17	Cory & Strong placer	Cory & Strong (1930)	E½ 16	24N	4E	M.D.	Gold	320 acres. R. 24, p. 195; R. 26, p. 389; B. 135, p. 233.
	Crown Point	Mary Hurley, 1676 Hayes St., San Francisco, Calif.	SE¼ 29, NE¼ 32	20N	6E	M.D.	Gold	17.36 acres patented land in the Mt. Springs district.
	Delano Paint mining claim	Mary Hurly, 1676 Hayes St., San Francisco, Calif.	SW¼ 29, NW¼ 32	20N	6E	M.D.	Mineral paint	20.66 acres patented land in the Mt. Springs district.
	Dewey lode	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	SW¼ 2, SE¼ 3	19N	6E	M.D.	Gold	4.54 acres patented land in the Forbestown district.
	Diamond Placer No. 1, Diamond Cherokee	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	Lot 4 & SW¼ NE¼ 28	21N	4E	M.D.	Gold	67.1 6acres patented land in the Cherokee district.
18	Dix drift mine	Bix Butte Mining Company, F. M. Maloney, Secretary, 206 E. C. Lyon Bldg., Reno, Nev. (1930)	S½ 22	24N	3E	M.D.	Gold	R. 12, p. 85; R. 13, p. 87; R. 15, pp. 201-202; R. 24, p. 195; R. 26, pp. 390-391.
	Elbow placer	Ruth Dodgson, Rt. 1, Box 39-A, Wheatland, Calif.	Lot 39 S½ 11 & N½ 14	25N	4E	M.D.	Gold	150.34 acres of patented land in the Stirling City district.
19	El Monte (Toadtown)	P. J. McHugh, DeSabla, Calif. (1930)	SW¼ 36	24N	3E	M.D.	Gold	R. 26, p. 372.

20	Emma (Nimshew) drift mine	Nimshew Gold Mining Company c/o John Erickson, 141 Sutter St., San Francisco, Calif. (1930)	14, 15, 23	23N	3E	M.D.	Gold	R. M. (Butte), p. 10; R. 11, p. 163; R. 15, p. 200; R. 24, p. 196; R. 26, p. 191.
21	Emma No. 2 placer	Robbers Roost Mining Company, 686 Sacramento St., San Francisco, Calif.	SE¼ 10	23N	3E	M.D.	Gold	160 acres of patented land in the DeSabla district, R. 11, p. 163; R. 15, p. 200; R. 24, p. 196; R. 26, p. 391.
	Equitable	Dorothy M. Dunkley, 686 Orim Ave., Oakland 10, Calif. ½ interest; Betty M. Oghura, 837 Chestnut St., Yreka, Calif. ½ interest.	SW¼ 2, NW¼ 11	19N	6E	M.D.	Gold	30 acres of patented land in the Forbestown district.
22	Ethel	Pacific Investment Company (1928)	N½ 3	22N	3E	M.D.	Gold	R. 24, p. 197; R. 26, pp. 391-392.
23	Exposition 1915, No. 1	George Schaafs, 24766 Niles Road, Hayward, Calif.	SW¼ 15	20N	7E	M.D.	Gold	19.55 acres patented land. R. 15 p. 215.
	Fayette & La Shalle	Frank Antrm, 2118 E. Park Place, Milwaukee, Wis.	SW¼ NW¼ 2, SE¼ NE¼ 3	19N	6E	M.D.	Gold	20 acres of patented land in the Forbestown district.
24	Genii Mining Company Lease	Magalia Mining Company, 910 American National Bank Co., San Francisco, Calif.	S½ 19, N½ 30, E½ NE¼ 25	23N 23N	4E 3E	M.D. M.D.	Gold	485 acres. R. 26, pp. 392-393.
25	Gold Bank Consolidated Quartz (Forbestown Consolidated)	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	Lots 47, 48, 49, 50, SE¼ 2, NE¼ 11, 1, 12	19N	6E	M.D.	Gold	R. M. (Butte) pp. 8, 9; R. 10, p. 125; R. 11, p. 162; R. 12, p. 83; R. 13, p. 85; R. 15, pp. 211, 216; R. 26, pp. 373-376. Leased to the Idaho Maryland Mines Corporation. Idle in 1948.
26	Golden Summit placer	Lewis Vanos and W. G. and Ira D. Rankin, Sterling City, Calif.	SE¼NE¼, NE¼SE¼, W½SE¼, E½SW¼, SE¼	25N	5E	M.D.	Gold	120 acres patented land. R. 13, p. 86; R. 15, p. 217.

Tabulated list of mines and prospects, Butte County, California—Continued

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B&M		
27	Gold Hill Dredging Company	Len Kister, Oroville, owns the land. It is leased to the Gold Hill Dredging Company, E. B. DeGolia, president, 311 California St., San Francisco, Calif.	10	18N	3E	M.D.	Gold	B. 135, p. 252.
28	Gold Mountain	J. B. O'Sullivan and E. L. Bacon, Los Angeles, Calif. (1930)	NW¼ 28	25N	4E	M.D.	Gold	R. 26, p. 376.
	Gold Nugget placer	Earl S. Ward, 1720 Bird St., Oroville, Calif.	Lot 38, NW¼NE¼ 14	25N	4E	M.D.	Gold	18 acres of land patented in the Sterling City district.
	Good Flat	J. H. Sharpe, Box 7, Oroville, Calif.	Lot 50, E½NE¼ 29	20N	4E	M.D.	Gold	9.63 acres patented in the Morris Ravine district.
	Grand View	Dorothy M. Dunkley, 689 Orino Ave., Oakland 10, Calif., ½ interest. Betty M. Ogburn, 837 Chestnut St., Yreka, Calif., ½ interest.	SW¼SW¼ 2, NW¼NW¼ 11	19N	6E	M.D.	Gold	30 acres patented in the Forbestown district.
	Grouse Quartz	Olive A. Walker, c/o Sterling City stage, Magalia, Calif.	SE¼30	25N	4E	M.D.	Gold	37.8 acres patented in the Sterling City district. Idle in 1948.
	Hazel Dell placer	Anna Grant McLean, 701 Post St., San Francisco, Calif.	SW¼NE¼, NW¼SE¼ 32	22N	5E	M.D.	Gold	Idle in 1948. Patented land in the Las Plumas district.
1	Helmke	Rae Helmke, c/o Bradley & Ekstrom, 320 Market St., San Francisco, Calif.	SE¼ 34 (?)	23N	3E	M.D.	Chromite	Magalia district. Worked in 1947; idle in 1948.

	Hendy placer	Evelyn P. Joslyn, Florence Lackey, and Daniel P. McIntyre, c/o Evelyn P. Joslyn, Oroville, Calif.	SW¼ 29, SE¼ 30	20N	4E	M.D.	Gold	67.5 acres patented in the Morris Ravine district.
	Homestake	Ed. E. and Chas. J. Strouse, 1121 40th St., Sacramento, Calif.	SE¼ 6, NE¼ 7	19N	6E	M.D.	Gold	40.348 acres patented in Mt. Springs district.
	Homestead lode	Mrs. Louis R. Lynds, 3008 Mable St., Berkeley 2, Calif.	SE¼ 10, SW¼ 11	19N	6E	M.D.	Gold	10.499 acres patented in the Forbestown district.
	Homestead quartz	Ethel W. Hurd and Raymond Williams, Box 82, Westwood, Calif.	SE¼ NE¼ 9	20N	4E	M.D.	Gold	19 acres patented in the Cherokee district.
	Honey Comb quartz	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	NW¼ SE¼ 3	19N	6E	M.D.	Gold	19.16 acres patented in the Forbestown district.
	Hornet lode	Lemuel L. Castle, Rt. 1, Box 157, Oroville, Calif.	SE¼ SE¼ 4	20N	4E	M.D.	Gold	18.6 acres patented in the Cherokee district. U.S. Survey No. 5232.
29	Hupp placer	G. G. Hupp, De Sabla, Calif., et al. (1930)	NW¼ 1, N½ SW¼ & N½ 2	23N 23N	3E 3E	M.D. M.D.	Gold	480 acres. R. 26, p. 393.
	Ida Bell	Arley I. and Gertrude M. Hetherington, c/o Alma E. Hogge, 685 Pamona Ave., Oroville, Calif.	E½ SW¼ 9	20N	4E	M.D.	Gold	55.4 acres patented land in the Cherokee district.
30	Indian Springs	Indian Springs Mining Co., c/o N. G. Torrison, De Sabla, Calif. (1930).	SW¼ 3, 10	23N	3E	M.D.	Gold	140 acres. R. 26, p. 394.
31	Inskip	John A. and Frank X. Feehan, 2239 Post St., San Francisco, Calif.	SE¼ SW¼ 29, NE¼ NW¼ 32	25N	4E	M.D.	Gold	Patented land in the Sterling district. R. 12, p. 84; R. 13, p. 87; R. 15, p. 217.
32	I.X.L. Quartz Ledge	Rolland E. and Harold F. Knapps, 1577 Shasta Ave., San Jose, Calif.	NW¼ 20	22N	4E	M.D.	Gold	20 acres patented in the Concaw district. R. 26, p. 376.

Tabulated list of mines and prospects, Butte County, California—Continued

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B&M		
	Jack & Jim	J. A. Gaumer and Alice Miles c/o J. A. Gaumer, Rt. 1, Oroville, Calif.	SE¼ SW¼ 1, NE¼ NW¼ 12	21N	3E	M.D.	Gold	190 acres patented in the Messila Valley district.
33	Jackpot (Golden Pool)	Herbert W. Furlong (1930)	SW¼ 32	22N	4E	M.D.	Gold	R. 26, pp. 394-396.
80	Kaiser, Henry J., Company (Betchel-Kaiser Rock Company)	Henry J. Kaiser Company, Kaiser Bldg., Oakland, Calif.	25, 35, 36	18N	3E	M.D.	Gravel and crushed rock	R. 26, pp. 409-410.
	Katydid quartz	H. J. Anderson, c/o Alma Lockie, Rt. 1, Box 162A, Paradise, Calif.	SE¼ 34	24N	3E	M.D.	Gold	114.4 acres patented in Sterling City district.
34	Kelly Hill	C. V. Bolton, 1122 Kohl Bldg., San Francisco, Calif.	W½ 27, SE¼ 28	23N	3E	M.D.	Gold	280 acres patented. Leased to the Magalia Reserve, Ltd. R. 12, p. 14; R. 15, p. 202; R. 24, p. 199; R. 26, p. 396.
81	Kemen gravel pit	The land is owned by H. G. Holmes, Magalia, Calif., and the pit is operated by J. C. Kemen, Paradise, Calif.	24	23N	3E	M.D.	Sand and gravel	
82	Kennedy gravel pit	J. J. Kennedy, Chico, Calif. via Nimshew stage.	18, 19	22N	3E	M.D.	Road metal.	
35	Keystone & Golden Fashee	Louise M. Wason, ⅓ interest, Chas. S. Burroughs et al., 1318 Park Ave., Chico, Calif., ⅓ interest.	Lot 60 E½ SE¼, SW¼, W½ SW¼ SE¼ 3	19N	6E	M.D.	Gold	40 acres patented in the Forbestown district. R. 10, p. 127; R. 12, p. 85; R. 15, p. 218.
36	Kickapoo	Mary M. and Wallace Dinsmore, c/o C. F. Aaron, Box 47, Marysville, Calif.	Lot 38, 12	20N	7E	M.D.	Gold	72.46 acres patented in the Clipper Mills district. R. 12, p. 85; R. 13, p. 83; R. 15, p. 199.

37	Lancha Plana Gold Dredging Company	Land is leased from William Bidsworth, Chico, Calif.	35	22N	2E	M.D.	Gold	Lancha Plana Gold Dredging Company, Lockeford, Calif., operation started in December 1945 B. 135, p. 234.
	Last Chance Lode	John A. and Frank X. Feehan, 2239 Post St., San Francisco, Calif.	29, 32	25N	4E	M.D.	Gold	Patented land in the Sterling City district.
	Last Chance	Kittie Greenwalt, 1081 E. 7th St., Chico, Calif.	NE¼NE¼, NE¼SE¼ NE¼ 5	22N	3E	M.D.	Gold	52 acres patented in the Centerville district.
	Levant quartz	Margaret J. Beek, 1795 Windsor Road, San Marino, Calif.	Lot 59, E½ 3	19N	6E	M.D.	Gold	10.3 acres patented in the Forbestown district.
38	Lewis	Harriet Lewis, Forbestown, Calif. (1930)	2, 11	19N	6E	M.D.	Gold	R. 26, p. 377.
	Little Frog quartz	Bertha M. Cohn, 904 Faust Ave., Pacific Grove, Calif.	NE¼SE¼ 29	23N	4E	M.D.	Gold	16⅔ acres patented in the Concaw district.
	Little Pippin	Oscar J. and Mabel J. Kaher, 1623 Bird St., Oroville, Calif.	20	23N	4E	M.D.	Gold	Patented land in the Concaw district.
5	Lott Ranch	C. F. Lott (1930)	12	20N	3E	M.D.	Coal	R. 11, p. 166; R. 24, p. 177; R. 26, p. 367.
	Love Point	Ed. E. and Chas. J. Strouse, 1121 40th St., Sacramento 16, Calif.	SE¼ 6, NE¼ 7	19N	6E	M.D.	Gold	40.348 acres patented in Mountain Springs district. U.S. Survey No. 5560.
39	Lucky John	Henry Martens, San Francisco, Calif. (1930)	SW¼SW¼ 2, NW¼ 11	22N	3E	M.D.	Gold	360 acres. R. 15, p. 203; R. 18, p. 259; R. 24, pp. 199-200; R. 26, pp. 397-398.
3	Lund	Nelson E. Lund, 290 Villa St., Oroville, Calif. (1930)	36 (?)	18N	4E	M.D.	Clay	R. 24, pp. 175-176; R. 26, pp. 364-367; B. 99, p. 65.
40	Lydia placer	Geo. L. Campbell, Rt. 1, Box 186, Paradise, Calif.	Lot 5, 36	24N	3E	M.D.	Gold	9.17 acres patented in the Sterling City district. R. M. (Butte), p. 8; R. 24, p. 201; R. 26, p. 398.

Tabulated list of mines and prospects, Butte County, California—Continued

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B&M		
41	Magalia (Perschbaker)	Magalia Mining Company, H. G. Holmes, president, Magalia, Calif.	SE¼ 13, 24	23N	3E	M.D.	Gold	R. 9, p. 28; R. 13, pp. 87-88; R. 15, p. 203; R. 26, pp. 398-400; R. 28, p. 298.
42	Mammoth-Gold Bank Consolidated	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	Lots 47, 48, 49, 50, Sec. 2, 11	19N	6E	M.D.	Gold	Patented land in the Forbestown district. R. 10, pp. 125-127; R. 11, p. 162; R. 12, p. 83; R. 13, p. 85; R. 15, p. 216; R. 26, pp. 374-376.
	Marble Walls and Marble Halls placer	Anna Grant McLean, 701 Post St., San Francisco, Calif.	32	22N	5E	M.D.	Gold	Patented land in the Las Plumas district.
83	Martin, Billie	Billie Martin, Chico, Calif.	7	20N	3E	M.D.	Sand and gravel	
84	Mathews, Roy	Roy Mathews, Rt. 1, Box 275-E Gridley, Calif.	SW¼, 33	18N	3E	M.D.	Sand and gravel	
43	McHugh prospect	P. J. McHugh, DeSabla, Calif.	SE¼SW¼ 36	24N	3E	M.D.	Gold	R. 26, pp. 377-378.
88	McLean talc	Anna Grant McLean, 701 Post St., San Francisco, Calif.	32	22N	5E	M.D.	Talc	19 acres patented in the Las Plumas district. R. 24, p. 210; R. 26, p. 412.
44	Mineral Slide (Magalia Consolidated)	Jack L. Post, 434 Wall St., Chico, Calif.	S½ 3, N½ 10	22N	3E	M.D.	Gold	Leased to Jonas L. Roe, et al., Boulder Creek, Calif. R. 8, p. 117; R. 12, p. 86; R. 15, p. 204; R. 24, p. 201; R. 25, pp. 400-401.
	Monte Christo	Edyth Dungan and A. W. Ford, c/o Edyth Dungan, P.O. Box 336, Pacific Grove, Calif.	9	20N	4E	M.D.	Gold	10 acres patented in the Cherokee district.

45	Morris Ravine (Butterfly, Goodall & Perkins)	Morris Ravine Mining Company, J. H. Sharpe, president, Box 7, Oroville, Calif.	29	20N	4E	M.D.	Gold	Leased to Split Rock Mines. R. M. (Butte), p. 10; R. 15, pp. 204-205; R. 18, p. 258; B. 135, p. 234.
46	Mountain House drift prospect	August Amend, Berry Creek, Calif.	Center 4	21N	6E	M.D.	Gold	R. 24, p. 202; R. 26, pp. 401-402.
	New Alvarado placer	H. J. Anderson, c/o Alma Lockie, Rt. 1, Box 162-A, Paradise, Calif.	SE¼ 34	24N	3E	M.D.	Gold	114.4 acres patented in the Sterling City district.
	New Era	J. O. Gaumer and Alice Miles, c/o J. O. Gaumer, Rt. 1, Oroville, Calif.	1, 12	21N	3E	M.D.	Gold	190 acres patented in the Messila Valley district.
47	Nisket Lode and Standard mine	E. J. James & Bros., Rt. 1, Oroville, Calif.	Lots 1, 4, 5, Sec. 16	20N	4E	M.D.	Gold	69 acres patented. R. 12, p. 89; R. 13, p. 93; R. 15, p. 223.
	North Star	Albion H. and Lash Bean, Bangor, Calif.	Lot 39, Sec. 12	20N	7E	M.D.	Gold	Patented land in the Clipper Mills district.
	Norton quartz	Edyth Dungan and A. W. Ford, c/o Edyth Dungan, P.O. Box 336, Pacific Grove, Calif.	NE¼ 9	20N	4E	M.D.	Gold	9.5 acres patented in the Cherokee district.
48	Nugget drift	Barton Smith, Paradise, Calif.	S½ 36	24N	3E	M.D.	Gold	R. 26, p. 402.
75	Ochre No. 1 and Ochre No. 2	Dora M. and LeRoy E. Black, 1096 National Ave., Chula Vista, Calif.	W½SE¼ 6	23N	4E	M.D.	Mineral paint	36 acres patented. R. M. (Butte), p. 12.
49	Oro Fino	Robbers Roost Mining Company, 903 Hobart Bldg., San Francisco, Calif. (1930)	10, 11	23N	3E	M.D.	Gold	360 acres. R. M. (Butte), p. 10; R. 8, pp. 118-119; R. 9, p. 28; R. 11, p. 160; R. 12, pp. 86-87; R. 13, pp. 89-90; R. 15, p. 207; R. 24, pp. 202-204; R. 26, pp. 402-403.
50	Oroville Gold Dredging Company	Oroville Gold Dredging Company, W. H. W. Wandesford, president, Oroville, Calif.	4	18N	3E	M.D.	Gold	The dredge has been idle since 1944 and it is now owned by the Reconstruction Corporation. B. 135, p. 234.

Tabulated list of mines and prospects, Butte County, California—Continued

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B&M		
	Oroville mine	Arley I. and Gertrude M. Hetherington, c/o Alma E. Hogge, 685 Pamona Ave., Oroville, Calif.	9	20N	4E	M.D.	Gold	55.4 acres patented in the Cherokee district.
	Panmarat Quartz lode	P. J. and Andy L. McHugh, Star Rt., Magalia, Calif.	Lot 39 in E½SW¼ 36	24N	3E	M.D.	Gold	Patented land in the Sterling City district.
2	Parks	Leased to A. Stevenson, Sacramento, Calif. T. W. S. Clark, C. M. McMallen and Irwin H. Reimers, (1943)	7	21N	4E	M.D.	Chromite	R. 39, p. 71.
	Paul Jones	Roy G., Helen M., and Mildred and Robert Waysalt, c/o General Delivery, Magalia, Calif.	SE¼ 27	24N	3E	M.D.	Gold	46.44 acres patented in the Faust district.
51	Phoenix	A. E. Jones, Woodleaf Star Rt., Oroville, Calif.	Lot 41, 28	19N	5E	M.D.	Gold	20.33 acres patented in the Wyandotte district. R. M. (Butte), pp. 8, 9; R. 12, pp. 87-88; R. 13, p. 90; R. 15, p. 220.
52	Pine Grove (Gold Bank Consolidated)	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	Lots 47, 48, 49, 50, Sec. 11	19N	6E	M.D.	Gold	Patented land in the Forbestown district.
53	Pitts (Old Bader, Mowry and Newman)	Mowry & Newman, San Francisco, Calif. (1930)	1, 2	22N	3E	M.D.	Gold	R. 18, pp. 260-261; R. 24, pp. 204-205; R. 26, pp. 403-404.
54	Porter	Sidney Wellington, 321 Montgomery St., Oroville, Calif. (1930)	17, 20	22N	4E	M.D.	Gold	R. 26, p. 378; R. 31, p. 6.
	Primal lode	W. O. Harrington and T. C. Hutchinson, Forbestown, Calif.	11	19N	6E	M.D.	Gold	14.94 acres patented in the Forbestown district.

55	Princess	Jess Whitlow, Magalia, Calif.	SE¼ 12, NE¼ 13	23N	3E	M.D.	Gold	320 acres patented. R. M. (Butte), p. 10; R. 13, p. 91; R. 15, p. 207; R. 26, p. 404.
56	Rainbow	E. L. Griffith, 214 Front St., San Francisco, Calif.	SE¼NW¼ & N½S½, 29	22N	4E	M.D.	Gold	20 acres patented in the Concaw district. R. 10, p. 131; R. 11, p. 158; R. 12, p. 88; R. 13, p. 91; R. 15, p. 221; R. 24, p. 186; R. 26, p. 378.
	Rattlesnake quartz	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	Lot 58, Sec. 2, 3	19N	6E	M.D.	Gold	10.46 acres patented in the Forbestown district.
	Red Gravel	Norman Spangler, c/o Chas. Colman and J. E. Cogswell, Nimshew stage, Chico, Calif.	NW¼SW¼, 4	22N	3E	M.D.	Gold	2.31 acres patented in the Centerville district.
57	Red Hill	Estate of I. R. Hall, Rt. 3, Box 495, Sebastapol, Calif.	19, 30	23N	4E	M.D.	Gold	80 acres patented in the Magalis district. R. 11, p. 158.
76	Richardson Spring	Richardson Springs Corporation, Richardson Springs, Calif.	17	23N	2E	M.D.	Mineral springs	R. 15, p. 225; R. 24, p. 208; R. 26, p. 408; U. S. G. S. Water-Supply Paper 238, p. 292.
	Roosevelt placer	Bertha M. Cohn, 904 Forest Ave., Pacific Grove, Calif.	NE¼SE¼ 29	23N	4E	M.D.	Gold	16⅔ acres patented in the Concaw district.
58	Rotten Boulder drift mine	Edgar Knox, Magalia, Calif. (1930)	W½W½, 20	22N	4E	M.D.	Gold	R. 24, p. 205; R. 26, pp. 404-405.
59	Royal (Best, Robinson) drift	Forest Snow, Magalia, Calif.	SW¼ 27, 34, 4	24N 23N	3E 3E	M.D. M.D.	Gold	R. 15, p. 207; R. 17, p. 417; R. 24, p. 205; R. 26, p. 405.
85	Sake and Sanders rock pit	Bill Sake and Ed. Sanders, Magalia, Calif.	NE¼ 25	23N	3E	M.D.	Road metal	
	Sampson lode	Mary K. Hicks, 2311 N St., Sacramento, Calif., and F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	10	19N	6E	M.D.	Gold	Patented land in the Forbestown district. Mineral survey No. 5983.
60	Shawnee (Alladin, McLain)	The land is assessed to the Diamond Match Company.	W½ 15	24N	3E	M.D.	Gold	The property is leased and operated by F. A. Willis.

Tabulated list of mines and prospects, Butte County, California—Continued

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B&M		
61	Silver Moon (Porphyry Point)	H. Bartram, Coutolanc, (1930)	S½NW¼ 18	23N	4E	M D	Gold	R. 26, pp. 378-379.
62	Southern Cross	Edel Mining Company, c/o Lester L. Roth, 3355 Pacific Ave., San Francisco, Calif.	SE¼ 32	20N	6E	M.D.	Gold	79.96 acres patented in the Mountain Springs district. R. M. (Butte), pp. 8, 9; R. 15, p. 222; R. 24, p. 187; R. 26, p. 379.
63	Springer Consolidated (Matheson) Mining Company	Garden Peach, 51 Clark St., Brooklyn 2, N. Y.	E½ 34	24N	3E	M.D.	Gold	44.15 acres patented. R. 13, p. 88; R. 15, p 219; R. 24, p. 187; R. 26, pp. 377, 380-381.
86	Stearns Sand & Gravel Company	Claude Stearns, Chico, Calif.	8	20N	3E	M.D.	Sand and gravel	
64	Steiffer (Joe S. Campbell) placer mine	P. B. Steiffer, Magalia, Calif.	SW¼ 1, SW¼, W½ NW¼ 12, E½NW¼ 13	23N	3E	M.D.	Gold	395 acres. R. M. (Butte), p. 10; R. 15, pp. 207-208; R. 17, p. 417; R. 18, p. 261; R. 24, pp. 206-207; R. 26, p. 406.
	Stowe Home Pine Grove quartz	F. J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	SW¼ 2	19N	6E	M.D.	Gold	4 acres patented in the Forbestown district.
	Sunset Mohawk	Mary Hurley, 1676 Hayes St., San Francisco, Calif.	28, 29, 32	20N	6E	M.D.	Gold	41.32 acres patented in the Mountain Springs district.
65	Surcease	Hoefling Bros., Box 786, Sacramento, Calif.	4, 5, 6, 7, 1, 3, 12, 25	21N 21N 22N	5E 4E 4E	M.D. M.D. M.D.	Gold	1,821.94 acres patented. R. 18, p. 261; R. 24, p. 189; R. 26, pp. 381-382; R. 31, p. 6.
4	Table Mountain Clay Products Company	L. F. Riley, president, Oroville, Calif. (1930)	SW¼ 22	20N	3E	M.D.	Clay	R. 24, p. 176; R. 26, pp. 366-367; B. 99, pp. 65-66.

	Tenderfoot quartz	Olive A. Walker, c/o Sterling City Stage, Magalia, Calif.	SE¼ 30	25N	4E	M.D.	Gold	Patented land in the Sterling City district.
	Terra Lava drift mine	John D. Hubbard	W½ 10	22N	3E	M.D.	Gold	80 acres patented. Leased to Charles A. Howe, Mesquite, Nevada.
	Tiger	Ray G. Hilen, Mima, Mildred and Robert Waycott, General Delivery, Magalia, Calif.	SE¼ 27	24N	3E	M.D.	Gold	46.44 acres patented in the Forest district.
	Tortoise placer	Fred J. Stoer, 3801 San Pablo Ave., Emeryville, Calif.	N½NE¼ & SE¼NE¼ 28	21N	4E	M.D.	Gold	120 acres patented in the Cherokee district.
66	Triumph Mine No. 1 & No. 2	Martha G. Higgins, Goodyears Bar, Calif.	N½ 22	20N	7E	M.D.	Gold	20.66 acres patented in the Feather Falls district. U.S. Survey No. 5468. R. 15, p. 223; R. 24, p. 190; R. 26, pp. 382-383.
67	Triumph Extension	Martha G. Higgins, Goodyears Bar, Calif.	S½ 15	20N	7E	M.D.	Gold	18.60 acres patented in the Feather Falls district.
87	Ultican, L. L., gravel plant	L. L. Ultican	36(?)	22N	1E	M.D.	Sand and gravel.	
	Venus quartz	Surcease Mining Company, Box 786, Sacramento, Calif.	Lot 38 W½ SW¼ 3	21N	4E	M.D.	Gold	20 acres patented in the Concaw district.
	Wannasha	Arley I. and Gertrude M. Hetherington, c/o Alma E. Hogge, 685 685 Pamona Ave., Oroville, Calif.	9	21N	4E	M.D.	Gold	55.4 acres patented in the Cherokee district.
	Welch placer	Lewis Venos and W. J. and Isa D. Rankin, Sterling City, Calif.	Lot 4, Sec. 20	25N	5E	M.D.	Gold	14.04 acres patented in the Sterling City district.
	West Branch placer	Lewis H. McLain, c/o Nimshew stage, Chico, Calif.	10	24N	3E	M.D.	Gold	80 acres patented in the Forest district.
68	Willard Consolidated quartz	Dakin Company c/o Oliver Dobson, 3753 Slauson Ave., Los Angeles 43, Calif.	SW¼NE¼ 30	23N	4E	M.D.	Gold	56 acres patented in the Magalia district. R.M. (Butte), p. 8; R. 11, p. 158; R. 15, p. 209.

Tabulated list of mines and prospects, Butte County, California—Continued

Map number	Name of claim or mine	Owner (name and address)	Location				Mineral product	Remarks and references
			Sec.	T.	R.	B&M		
69	William George lode	½ interest, Dorothy M. Dunkley, 689 Orimo Ave., Oakland 10, Calif., ½ interest, Betty M. Ogburn, 837 Chestnut St., Yreka, Calif.	SE¼SE¼ 2, NE¼NE¼ 11	19N	6E	M.D.	Gold	30 acres patented in the Forbestown district. R.M. (Butte) pp. 8, 9.
70	Wyoming (Black Diamond)	E. N. Understock and Mattye, M. Understock, Magalia, Calif.	NE¼ 34	24N	3E	M.D.	Gold	34 acres in the Butte Creek district. R. 24, p. 193; R. 26, p. 386.
	Yankee Bar	El Dorado Limestone Co., c/o J. H. Bell, Shingle, Calif.	E½ Lot 15, Lot 16, Sec. 24	22N	4E	M.D.	Gold	56.7 acres patented in the Concaw district.
71	Yuba Biggs dredge No. 1	Yuba Consolidated Gold Fields, 351 California St., San Francisco, Calif.	15	18N	3E	M.D.	Gold	Between Walnut & Cherry St., 0.4 mile east of Larkin Road. Land is leased from Virginia Hixon.
72	Yuba dredge No. 2	Yuba Consolidated Gold Fields, 351 California St., San Francisco, Calif.	15	18N	3E	M.D.	Gold	This dredge capsized in 1942 and has been dismantled except for the steel hull. It is located on Palm Ave., half a mile east of Larkin Road.
73	Yuba dredge No. 3	Yuba Consolidated Gold Fields, 351 California St., San Francisco, Calif.	15	18N	3E	M.D.	Gold	Located on Almon Ave. between Walnut & Palm Aves., and 0.4 mile east of Larkin Road. The land is leased from Sarah V. Hixon, Oroville, Calif. B. 135, p. 235.
	Yuba placer	B. C. Clark & Stent, Sutter Creek, Calif.	W½NE¼ 29	20N	4E	M.D.	Gold	48 acres patented in the Morris Ravine district.
	Zig Zag quartz	S. A. Vandergrift, Sterling City Calif.	NE¼ 30	25N	4E	M.D.	Gold	Sterling City district. Patented land.

ROOFING GRANULES IN THE SOUTHWEST *

By Stuart H. Ingram **

OUTLINE OF REPORT

Page
Introduction ---- 455
Types of roofing ---- 455
Growth of the industry ---- 456
Specifications for raw material ---- 458
Acknowledgments ---- 458

INTRODUCTION

Early man lived in the open with the rest of the animals. He shivered in cold and wet weather, and in summer hunted shade against the sun. With dim intelligence he grasped the comfort and convenience of shelter, found a cave and established himself therein. Possibly because caves were not to be found everywhere, or possibly because even in those days housing or cave shortages existed, a stimulus for construction of artificial shelter was provided, and man started in the construction business. He has been continuing it ever since, and his progress toward civilization has been greatly aided by his increasing skill in building.

Of all parts of a building, the roof is perhaps most important, and almost all available materials, such as grass and thatch, wood, mud and leaves, pottery, and metals, have been used at some time in some locality. Yet the search for new materials and the improvement of old ones continues.

A recent development is the use of a combination of felt, asphalt, and rock. The extraction of these from the earth, their refining and preparation, and the subsequent marketing and application of the finished products, form an important industry in the mining world. The Minerals Yearbook for 1945 states that in that year the United States consumed for roofing 2,049,685 tons of asphalt and 1,045,280 tons of rock granules, which together represented more than $30,000,000 worth of raw materials. Although this value was greatly exceeded by that of iron ore, which was more than a billion dollars; copper, which was $185,000,000; and aluminum, which was $142,000,000; it was comparable to that of lead, which was $45,000,000, and gold, which was $32,000,000; and it was far larger than that of antimony, cadmium, magnesium, nickel, silver, vanadium, and tungsten.

TYPES OF ROOFING

The combination of felt, asphalt, and rock are used in two distinct types of roofing. In one, the components are carefully selected and purchased by a roofing manufacturer who combines them into a finished roofing which is sold ready to lay. In the other, the components are selected and purchased for each job by the roofer or roofing contractor, who combines them only when actually laying the roof. The required number of alternate layers of asphalt and felt are applied and the final coat of asphalt is covered with granules while it is still hot. Each type of roofing has its own granule specifications. Thus two kinds of granules are produced, each of which is marketed along lines peculiar to its method of application.

---

* Paper presented at Los Angeles meeting of American Institute of Mining and Metallurgical Engineers, October 15, 1948. Permission to print granted by courtesy of Secretary of the Institute, 29 West 39th Street, New York 18, New York.

** Consulting mining engineer; Member, American Institute of Mining Engineers.

A small granule, about 14 mesh, is needed for the prepared roofing. This roofing is sold in various weights and colors, both in rolls and in many forms of shingles. The surface is ordinarily flat, because the last step of manufacturing is rolling, but some relief can be obtained by scoring. By variations in color and shape of shingle, other roofing materials can be imitated, so it is adaptable to many architectural styles. Also, it can be used successfully on roofs of any pitch, but in general it is more satisfactory on those that have a pitch of 3½ inches per foot or more. The prepared roofing is made in large quantities and hence at low cost; and as it is easy to apply, it is a favorite with the layman who does his own roofing. In the marketing of the small granule, a few large producers supply a few large consumers.

The built-up type of roofing is limited in its application to roofs with a pitch of 3½ inches per foot or less, but in that field it has few equals in quality. It can be made absolutely water-tight for at least 30 years. In its construction a coarser granule is used, generally about a quarter of an inch in size. The color range is the same as that of the granules in the prepared roofing, but as each roof is a special job the blending of granules makes infinite color possibilities. The coarse granules cause a rough texture that is pleasing in appearance, and which is difficult to obtain with the prepared roofing. The marketing of these granules is mostly on a retail basis, because each roof represents an individual transaction between a producer and a roofer. This results in many producers and consumers.

Until recently most of the built-up roofs were used only on commercial buildings where they were hidden by firewalls, or on residences where the roof played little part in the architectural design. Because appearance was negligible and the only function of the granule was to protect the asphalt from weathering, ordinary pea-gravel was found satisfactory. Also as it was cheap and could be purchased easily by the roofer from the nearest sand and gravel plant, it was generally used.

In contrast to this, prepared roofing needed sales appeal, which the manufacturer supplied with color. Rocks of natural color that had the other necessary requirements were sought and used. However, manufacturing required standardization, and it was found difficult to keep color uniform when even slight color changes were encountered in different parts of the quarry. As a result, methods of artificially coloring the granules were studied. The coloring material had to be permanently bonded to the granule, because the color needed to be fast under all weather conditions for the duration of the life of the roof. Costly mistakes were made, but the problem was solved, and today there are several successful methods of coloring granules. The one used most generally consists of applying a low-fusion colored ceramic glaze to the granule at a temperature of approximately 1000° F. In another process a zinc-oxide phosphoric-acid glaze is applied to the granule. A third process is to fire buff- or red-burning clays to a semi-vitreous state and then to crush and screen them.

GROWTH OF THE INDUSTRY

Although industry in southern California has been active in mining and preparing naturally colored granules, and has contributed much toward the development of the colored granule, the industry has had a much larger growth in the eastern states, where raw materials were more adaptable. Eastern slates were more uniform in color and texture than California volcanics, and the flat cleavage was advantageous for breaking the rock. The western rocks had greater variety and strength of color, but those advantages were not sufficient to hinder the erection of large roofing-granule plants in the east. So for years, the granules required by California's roofing manufacturers have been supplied from the eastern plants.

However, industrial changes indicate that California will soon supply its own needs, and possibly even export granules. The growth in population and consequent intense construction in the state has created a large market. Foreseeing this condition several years ago, the Minnesota Mining and Manufacturing Company, operators of several large granule plants in the east, erected a plant east of Corona, California. Their intensive geologic study was instrumental in discovering a deposit almost ideal for granule manufacture. It was a hard trap rock with good breakage qualities and with the texture and composition to take color well. The rock had formerly been quarried for road-building material and the exposed quarry faces did much toward proving the extent and uniformity of the deposit.

The plant has a daily capacity of more than 500 tons. Stage crushing is employed with intermediate removal of fines. The screening system is elaborate and involves a final rescreening of the finished product to remove tramp oversize and the last traces of fines and dust. The plant is steel and concrete throughout with full provision for elimination and removal of dust. The coloring is done in batches, with careful adherence to color standards. Color uniformity was further improved by blending in making up each shipment. This plant will go far toward filling small-granule needs and relieving roofing manufacturers of heavy freight charges, and should help to enlarge their market area.

The large granules have almost entirely been supplied from local sources. The market for these will probably continue to increase, partly as a result of the current trend in architecture that emphasizes flat roofs, for which the built-up type of roofing is particularly adaptable. With this trend, white roofs have been introduced which are supposed to effect heat insulation through reflection. The white color is obtained either by using white granules or by painting gray granules. If the granules are painted they must be smaller than pea-gravel, carefully sized, and free from dust. The white granules are composed of dolomite or limestone, preferably dolomite, for it is slightly more coarsely crystalline.

Recent demand for white granules is far greater than established dealers can supply. As a result, firstly, inferior or improperly prepared material containing dust or off-color particles is being sold, to the detriment of the industry; and secondly, colored coarse granules are being offered as a substitute. The first situation can be overcome by increased wariness of buyers and the opening of new quarries of better material. The effect of the second is hard to predict.

Architects and designers are slowly realizing the possibilities of color in built-up asphalt-and-granule roofs. Although insulation by reflection is important, so is the annoyance to close neighbors of the glare from a sunlit white roof. Investigations are being made to determine whether it is possible to obtain the same insulation effect with other colors. At any rate the large colored granule is now being presented to the building industry, and if it gains approval, will be for an entirely new market. This market will develop slowly, however, for as yet no dealers have stocks of different colors on hand from which selections can be made. Present business is directly between a roofer and a producer who frequently has only one color to sell.

One progressive firm, the Gravellite Company, which has a plant at Puente, California, is specializing in the production of coarse artificially colored granules. They have complete screening facilities and a batch-coloring plant where the color is applied by fusing a ceramic glaze containing oxide of the desired color to the base rock at a temperature of about 1000° F. Several colors are being offered, and more will appear as the demand increases.

SPECIFICATIONS FOR RAW MATERIAL

Any deposit that is to be a source of roofing-granule material must be within economical hauling distance of the point of use. The rock must be hard enough to resist size breakdown during shipping and handling, and must have fracture qualities that permit reduction to the required size without an overproduction of fines. It must be weather resistant, bond well with asphalt, and contain no soluble salt that would tend to destroy either of these properties. If white, the rock should be a pure, almost dazzling white, with no iron oxide seams or discolored areas. If not white, the whole deposit should be uniform in color, and opaque to ultra-violet light. Even then it will be desirable to open and work the quarry so as to be able to prepare shipments blended from all parts of it.

If the rock is to be colored, in addition to the qualities already mentioned, it should have a uniform texture throughout the deposit, for this may determine the amount of color to be absorbed. Also it must bond permanently with the coloring medium, and must be free from metallic oxides that might contaminate the color glazing. Finally, it should be a neutral color so a minimum amount of pigment can be used.

Crushing at the quarry is generally best because of freight savings on the fines. Some rocks lose more than 50 percent during crushing, and furthermore, if the crushing is done in an urban plant, disposal of the fines can be very costly. On the other hand, fines and dust are always produced in some measure by handling, and dust is particularly objectionable as it interfered with bonding both to asphalt and to color glaze. Hence after long hauling or excessive handling, the granules may have to be rescreened to be serviceable.

Comparison of pea-gravel to rock meeting the above specification shows the progress which has been made in the industry, and perhaps further experience will place even narrower limits on the choice of suitable rock. California has a tremendous back country with a wide range of geological formations, in which rocks meeting the most exact specifications surely can be found.

ACKNOWLEDGMENTS

In the preparation of this paper the author has been greatly assisted by Dr. John H. Stanko, Chemical Engineer of San Marino; and by various officials of the Minnesota Mining and Manufacturing Company, particularly Mr. John A. Brown, chief geologist, Mr. R. E. Gundlach, plant manager, and Mr. L. W. Kanninen, plant superintendent.

THE WESTERN PULP AND PAPER INDUSTRY AS A CONSUMER OF CHEMICALS *

By R. G. Mispley **

OUTLINE OF REPORT

	Page
Introduction	459
Pulping processes	460
Sulphite process	460
Sulphate (Kraft) and soda processes	460
Chemicals used for primary pulp production	460
Sulphur	460
Limestone	460
Lime	461
Salt cake	461
Soda ash	462
Chemicals used for secondary pulp production	462
Caustic soda	462
Chlorine	462
Other bleaching agents	462
Sizing materials	462
Rosin	462
Alum	462
Sodium silicate	462
Starch	463
Other sizing agents	463
Fillers and coating materials	463
Clay	463
Titanium dioxide	463
Other fillers	463
Dyestuffs	463
Miscellaneous chemicals	463
Opportunities for development of western resources	463
Acknowledgments	464

INTRODUCTION

The pulp and paper industry is one of the largest consumers of chemical raw materials in the United States. These materials are used throughout all stages of the manufacture, from pulping to the final finishing of the product. Some of the chemicals are processing agents that release the cellulose fibre from its associated non-fibrous constituents; others become an integral part of the product. Upon the latter depends the diversification of commodity.

In assembling statistics on pulp and paper production, a geographical breakdown becomes apparent. This breakdown, however, does not appear for the raw materials used.

Among the Pacific Coast states, Washington is the largest pulp producer. As table 2 shows, in 1946 half of this pulp was converted into paper. Oregon produced slightly more pulp than paper; and California, which produced very little pulp, produced a large amount of paper. Most of the California paper was board, saturating, and roofing, wherein large quantities of waste paper are also used.

---

* Paper presented before the Western Chemical Market Research Group, Pacific Industrial Conference, Pacific Chemical Exposition, at the Civic Auditorium, San Francisco, California, October 21, 1947.

** Assistant Technical Director, Central Technical Department, Crown Zellerbach Corporation, Camas, Washington. Manuscript submitted for publication December 1948.

Table 1. Production and consumption of pulp, paper, and waste paper in the United States during 1946

	Production (tons)	Consumption (tons)
Pulp	10,605,000	12,090,000
Paper	19,180,000	22,410,000*
Waste Paper	—	7,300,000

* Per capita paper consumption during 1946 was 320 lbs.

Table 2. Production of pulp and paper in the western (Pacific Coast) states and British Columbia during 1946

State	Pulp (tons)	Paper (tons)
Washington	1,333,000	725,000
Oregon	407,000	390.000
California	14,000	450,000
British Columbia	500,000	400,000
Total	1,754,000	1,565,000

PULPING PROCESSES

The pulping processes employed on the Pacific Coast include the sulphite, the sulphate (Kraft), and the soda processes. Until 1947, the sulphite process was the one most used; more recently, use of the Kraft process has increased.

Sulphite Process. In the sulphite process, cellulose is freed from lignin and other incrusting materials by mild acid hydrolysis. Sulphurous acid is used in connection with a suitable base, the most common being lime. However, dolomite is also widely used, and ammonia is in commercial production in one large pulp mill. Magnesia base has also been developed, and is expected to find wide application in the industry.

Sulphate (Kraft) and Soda Processes. The sulphate and soda processes are very similar, in that in each an alkali at high temperature is used to dissolve lignin and other incrustants in wood, so that cellulose is freed in fibrous form. In the soda process, soda ash and lime produce a caustic-soda cooking liquor. In the sulphate process, a caustic-soda liquor is also used, but a portion of the active alkali is sodium sulphide.

CHEMICALS USED FOR PRIMARY PULP PRODUCTION

Sulphur. Sulphur, most of which comes from Louisiana and Texas, is the basic raw material used in the sulphite process. It is burned to form SO_2, which reacts in the presence of water with limestone (or one of the other bases) to form a mixture of calcium bisulphite and sulphurous acid. From 200 to 300 pounds of sulphur are required per ton of pulp. Sulphur is also used in the sulphate process, either as elemental sulphur which provides proper adjustment of the cooking liquor, or to react with soda ash to produce synthetic salt cake.

Limestone. Limestone is used in the manufacture of sulphite cooking liquor.

Table 3. Approximate annual consumption of chemicals by the pulp and paper industry

Chemical	Source of Pacific Coast supply	U.S. consumption		Pacific Coast consumption (tons)
		Tons	Percent of total U.S. prod.	
Sulphur	Imported	400,000	10	145,000
Limestone	Local	440,000	—	173,000
Lime	Local	500,000	12	50,000
Salt cake	Local	650,000	100	60,000
Soda ash	Local	150,000	5	10,000
Caustic soda	Local	110,000	6	30,000
Chlorine	Local	250,000	30	50,000
Rosin	Imported	100,000	20	10,000
Alum	Local	150,000	35	15,000
Clay	Imported	600,000	60	30,000
Titanium pigments	Imported	30,000	—	—
Talc	Local	30,000	—	—
Sodium silicate	Local	400,000	40	—
Starch	Imported	125,000	10	—
Dyestuffs	Imported	25,000	30	—
Casein	Loc. & imp.	10,000	—	—
Soya bean*	Imported	35,000	—	—
Calcium carbonate	Imported	75,000	—	—
Glycerine	Local	6,000	—	—
Sugar, invert	Imported	5,000	—	—
Sulphuric acid	Local	9,000	—	—
Wax	Loc. & imp.	100,000	—	—
Asphalt	Local	—	—	7,000
Glue	Local	8,000	—	—
Sodium aluninate	Imported	5,000	—	—
Enzymes	Imported	500	—	—

* Tonnage of beans processed into products used by the paper industry.

Table 4. Approximate annual production of the pulp and paper industry

	U.S. production (tons)	Pacific Coast production	
		Tons	Percent of total U.S. tonnage
Pulp	10,605,000	1,754,000	17.5
Sulphate	4,597,000	414,000	9.0
Sulphite	2,476,000	966,000	39.0
Mechanical	1,812,000	312,000	17.0
Soda	466,000	21,000	4.5
Others	1,254,000	—	—
Paper	19,180,000	1,565,000	7.5
Board	8,450,000	450,000	5.0

Lime. The major percentage of lime consumed by the pulp and paper industry is used in the sulphate and soda processes. An efficient lime-recovery method in these processes precludes a much greater usage. Some lime, essentially dolomitic, is used for the preparation of sulphite cooking acid. Lime is also a basic ingredient in the production of calcium-hypochlorite bleach liquor, in the bleaching process, and in the cooking of rags and straw.

Salt Cake. Sodium sulphate (salt cake) reduced to the sulphide is the basic component of the sulphate pulping process. Concentration is maintained in the cooking liquor at a predetermined level to produce the particular pulp desired in the mill. The chemical is derived from three sources—natural, synthetic, and by-product. The 60,000 tons used annually on the Pacific Coast come, for the most part, from natural deposits in California.

The sulphate process depends for its economic success entirely upon the efficiency of chemical recovery. Inasmuch as the percentage of recovery varies widely, salt cake usage likewise varies widely. Normally, from 175 to 400 pounds of salt cake are required per ton of finished pulp.

Soda Ash. Soda ash (sodium carbonate) is a source of the alkali used in the preparation of sulphate and soda cooking liquors. It is used to reduce sulphidity to the desired percentage in the sulphate process, and is the essential chemical in the liquor in the soda process. Soda ash is the alkali used in the cooking of rosins for the preparation of rosin size. In conjunction with other alkalis, it is used in the de-inking process in reclaiming waste paper.

CHEMICALS USED FOR SECONDARY PULP PRODUCTION

Caustic Soda. Caustic soda is a secondary pulping chemical used in preparing purified cellulose for rayon pulps, and in the multi-stage bleaching of sulphate pulps. Its effect is to remove chlorinated products in the primary stages of the bleaching process.

Chlorine. In one form or another, chlorine finds application in most bleaching processes. These secondary cooking processes accomplish the final preparation of the pulp as a raw material for the paper mill. Because of the rapid increase in production of bleached pulp, chlorine is very important to the industry. From 40 to 60 percent of the total amount required is used in its original form in the primary stages of bleaching, in which the pulp is chlorinated. The pulp is then washed, either with water or with a caustic solution, to remove the chlorinated lignin product, and is passed through a series of bleach liquors (calcium hypochlorite) to obtain the brightness desired. The multi-stage hypochlorite bleach has been found more economical, and produces a superior quality of pulp, to the single-stage bleach. Chlorine is also used in the treating of process water to control bacteria, and in combination with other materials, to control the slime in pulp.

Other Bleaching Agents. Zinc hydrosulphite and sodium hydrosulphite are used in minor quantities for brightening effect, rather than a high degree of bleaching. A newly developed process for the bleaching of groundwood, or mechanical pulp, uses hydrogen and sodium peroxides.

SIZING MATERIALS

A greater variety of chemicals is used in the manufacture of paper than in the pulping industry, for paper very seldom consists of fibre alone. Additives, such as rosin, alum, sodium silicate, starch, wax, asphalt, etc., are required to produce special characteristics.

Rosin. Rosin is the most important of the sizing materials. A wide variety of grades are used. The chief sources are the woods and gums of southern pine forests.

Alum. A necessary adjunct to the use of rosin size is papermaker's alum, the precipitant for rosin. Alum is also used for pH control, water treatment, and fibre and filler recovery; as a glue precipitant, and as a mordant in dyeing.

Sodium Silicate. Sodium silicate is extensively used as an adhesive for corrugated and solid fibreboard, in the de-inking of waste paper, and as a sizing agent.

Starch. Starch is used chiefly as surface sizing for bond, ledger, envelope, and similar papers, to provide a good writing and erasing surface. It is also used as an adhesive in paper coating; a bonding material added to the beater or paper machine system; and an adhesive for envelopes, postage stamps, bags, and gummed tape.

For the past few years, the use of starch in the paper industry has been curtailed, as a result of unsettled world conditions. Tapioca from the East Indies has not been available; and the minor quantity from other sources has been in demand for food. Potato starch has always been too expensive, and its quality too variable. Corn starch, the best product, has been difficultly obtainable. However, these conditions are rapidly becoming better.

Other Sizing Agents. Minor amounts of wax, asphalt, soya bean flour and protein, casein, and glue, are also used as sizing agents.

FILLERS AND COATING MATERIALS

Many different pigments are used, both natural minerals and manufactured chemicals, to achieve the desired opacity, printability, color, smoothness, and softness of finished paper.

Clay. Clay is at present the most widely used pigment, and its use is rapidly increasing. It is only recently, however, that any appreciable amount has been used by the Pacific Coast industry.

Titanium Dioxide. Titanium dioxide is the pigment that produces opacity in waxed paper, its high refractive index making it especially suitable for this purpose. Titanium dioxide is extended with barium and calcium sulphates for some uses. It is estimated that 30,000 tons of such pigments are required annually.

Other Fillers. Other fillers which are used for special effects are talc, calcium carbonate, zinc sulphide and oxide, lithopone, blanc fixe, and diatomaceous earth.

DYESTUFFS

To color or tint the various papers to satisfy customer requirements, almost 25,000 tons of dyestuffs are consumed annually. This comprises about 30 percent of the total production.

MISCELLANEOUS CHEMICALS

There are certain other miscellaneous chemicals which are used in minor quantities by the pulp and paper industry, but which are, nevertheless, indispensable. Among these are sulphuric acid for the production of parchment paper; glycerine and other plasticizing agents for glassine and parchment papers; synthetic resins of urea, melamine, and phenol base for wet strength, abrasion resistance, and impregnating of paper-base plastics; enzymes for starch conversion; paraffin wax for food papers of all kinds; and asphalt for the production of building papers, felts, and roofing.

OPPORTUNITIES FOR DEVELOPMENT OF WESTERN RESOURCES

The foregoing paragraphs have presented in brief manner the various chemicals utilized in the pulp and paper industry. Some of these can be procured in any part of the country; others are indigenous to one section. In the following paragraphs opportunities for development of western resources to supply the pulp and paper industry are discussed.

Clay is a very important material in the production of paper. England has always been the source of high-quality china clay. However, deposits satisfactory for most purposes have been developed in Georgia. There are also extensive clay deposits in the west, most of them characterized by low color and covered by considerable overburden; these might or might not be able to produce a material acceptable to the paper industry. The clay would not necessarily need to compete with those now used, for in many applications lower brightness would be acceptable.

Alum, which is widely used in the paper industry, has recently been produced from high-grade bauxite from the south.

Another development of interest to the paper industry is the production of the guar bean in Arizona. Just prior to World War II, locust-bean gum imported from the Mediterranean was being used to produce a high wet-strength factor in paper towelling. When the supply was cut off by the war, an extensive search was made for a suitable substitute. It was found that guar bean gum was superior to locust bean gum, and that the guar bean could be grown on marginal soils in Arizona and California, serving as an erosion control and soil conditioner, as well as an important primary product for the paper industry. Use of the guar bean is now in the semi-commercial stage; for a time, milling was a problem, but now experimental quantities of the gum are available.

If an adequate supply of uniform-quality potato starch could be assured, to compete economically with corn starch, there would be a large market furnished by the paper industry. Plants in Idaho, Oregon, California, and Washington are now attacking this problem in cooperation with the paper industry.

Plans for local production of peroxide have been made, and a market for the chemical is now needed. Should the use of the peroxide bleaching process for groundwood pulps increase to an appreciable volume, the market would be established.

ACKNOWLEDGMENTS

In closing, the author wishes to acknowledge his indebtedness to many sources of information, both published and unpublished. Especially appreciated is the assistance given by Mr. E. N. Poor, Chairman, Nonfiberous Raw Materials Committee, Technical Association of the Pulp and Paper Industry.

MINING LAW IN RECENT YEARS *

By William E. Colby **

OUTLINE OF REPORT

Page
The federal public land system 465
Federal Land Department now the "Bureau of Land Management" 468
The public land surveys 469
Public surveys and resurveys 470
The classification of public lands as to character 471
United States Geological Survey 472
State geological surveys 473
Spanish and Mexican grants 473
Land grants to states 478
Time when state's title to school land takes effect 481
Indemnity grants in lieu of lands in school sections 485
Act of 1927—granting mineral lands in school sections to states 487
Amendment of May 2, 1932 488
Act of June 21, 1934 489

The Federal Public Land System.[1] With the acquisition by the federal government of the vast territory lying to the west of the original colonies, by cession from these colonies, some sort of a national land system became imperative.

There had been two distinct systems of public land disposal in operation in the original colonies and the states which succeeded them. The New England colonies early in the eighteenth century had laid out rectangular townships, whereby common or surplus land, particularly in the vicinity of towns, was divided into surveyed tracts prior to sale and settlement. Townships six miles square were favored, but some were eight and others ten miles square. Another system had arisen in the southern colonies, where settlers and purchasers were granted a varying acreage of land which they were authorized to select out of unappropriated domain and to have identified by survey. This latter system resulted in carving up the available land into irregular parcels or ''indiscriminate locations'' without any coordinated surveys.

In the spring of 1784 the Continental Congress appointed a committee, with Thomas Jefferson as chairman, to recommend a plan for the disposition of the federal public domain. This committee reported unanimously in favor of the distinctly New England system of methodical rectangular surveys, although three of its five members were from southern states where the other system of "indiscriminate locations" was in force. It recommended that, prior to sale, the public domain be divided into "hundreds" by laying out townships ten geographical miles square, with interior lots one geographical mile (6086.4 ft.) square, each containing 850.4 acres. This report was in Jefferson's handwriting, though he did not "invent" the system which already had its New England prototypes. The Continental Congress, however, did not adopt the plan. George Washington,[2] a land surveyor by training and profession, that same summer made a journey into this wild, Indian-inhabited region lying to the west and gathered much information regarding it, which he communicated to Congress with his recommendations as to its control and disposition.

---

* This is the second of a contemplated series of articles intended to supplement the 3rd edition of Lindley on Mines (1914) and bring the subject to date. The first article appeared in September, 1945 in 33 Calif. L. Rev. 368-387. and in the California Journal of Mines and Geology, vol. 44, pp. 279-292, July 1948. Lindley on Mines might well have been entitled Lindley on Mines and the Public Domain, for his outstanding text on mines also deals extensively with the laws applicable to non-mineral public lands. This was essential, for many of the legal problems involving mineral lands can only be correctly understood when treated in conjunction with a background knowledge of the non-mineral land laws upon which the mining laws impinge. Consequently, this second article, dealing as it does with the origin and growth of the federal public land system and bringing down to date that portion of Lindley on Mines devoted to this phase of the general subject, might well be entitled *The Law of the Public Domain in Recent Years.*

** Member of the San Francisco Bar; Lecturer on the Law of Mines and Waters, University of California, 1911-1937; LL.D., University of California, 1937; Assistant Editor, Lindley on Mines (3rd ed. 1914).

[1] This supplementary article contains much historical information regarding our federal public land system which does not appear in Lindley on Mines and which is deemed of sufficient importance and interest to present here. Much of this additional information is found in Treat, The National Land System (1910) and in Donaldson, The Public Domain (1884), and the writer expresses his indebtedness to these excellent sources of material.

In March, 1785 the Continental Congress again appointed a committee, which also recommended dividing the federally owned lands into rectangular townships, reducing the size to seven miles square and substituting statute for geographical miles. The land when surveyed was to be sold at auction with a minimum price of $1.00 per acre. On May 20, 1785 the Continental Congress passed a "Land Ordinance," which provided that the federal public domain should be surveyed and divided into townships six miles square. These townships were to be offered for sale, some as a whole and each alternate townships in lots [3] of one square mile each. This ordinance provided for the sale of these lands on specified terms, and certain lots (sections) in each township were reserved for future disposition, as was also "one-third part of all gold, silver, lead, and copper mines." [4] The sixteenth lot (section) in each township was reserved for the maintenance of public schools. One-seventh of the entire area was made subject to the claims of the Continental soldiers, and a minimum price of a dollar per acre was established. This land ordinance constitutes the foundation of our federal land system, and, with minor changes, it is the method of subdividing public land which has since been followed consistently for more than a century and a half. The surveys of public lands were to be made by surveyors chosen by the Congress, one from each state and all acting under the direction of the "Geographer of the United States." Some surveys were completed under this system but hostile Indians were a serious menace, not only to the surveyors, but to the settlers who occupied the surveyed lands.

The Constitution of the United States, drafted by the Federal Convention of 1787, was ratified and became effective September 13, 1788, and the first Congress authorized by the Constitution was elected and then assembled in March, 1789. The Constitution provided:

> The Congress shall have power to dispose of and make all needful Rules and Regulations respecting the Territory or other property belonging to the United States . . . . (Article IV, Section 3.)

This provision gives Congress plenary power over the federally owned public lands, and its constitutional power in this respect "is without limitation. Thus neither the courts nor the executive agencies could proceed contrary to an Act of Congress in this congressional area of National power.''[5]

---

[2] George Washington was a member of the Continental Congress, representing Virginia.

[3] The word "section," though used in the debates, was not used in the ordinance as passed, and it first appears in the later Act of 1796. Thereafter it replaced the word "lot" and for nearly 150 years bears the name applied to one surveyed square mile of the public domain.

[4] This reservation of a fractional portion of the metal mines named was a relic of the Royal Charters under authority of which the original colonies were established. These charters contained similar reservations. There is no record that this provision was ever put to practical use.

The adoption of the Constitution had the effect of nullifying the action previously taken by the Continental Congress. It was urgent, therefore, that the new Congress early declare itself on land policy in order that the sale and settlement of public lands, which had been authorized in a small way in the growing West, should continue on a much larger scale. Alexander Hamilton, then Secretary of the Treasury, was requested by Congress to prepare a uniform plan of public land disposal. His report ignored the Land Ordinance of 1785 of the Continental Congress, with its provision for prior survey of townships, and recommended instead a modified system of ''indiscriminate locations.''[6] Bitter debates ensued on the respective merits of the two irreconcilable systems. In spite of the need for revenue and the urgency resulting from the unlawful ''squatting'' of pioneer settlers on the public domain, Congress only debated and delayed positive action.[7] Tremendous pressure on Congress was exerted by speculators who offered to purchase large tracts of land in single units embracing millions of acres. The scandal which developed from these offers further added to the delay. There was serious conflict between congressmen who favored such sales of large areas to moneyed purchasers, with its immediate returns for the federal treasury, and those who wished the land to be taken up in small tracts by actual settlers, which meant delay in realizing funds. Finally a bill was passed and approved by President Washington on May 18, 1796.[8] The plan originally adopted by the Land Ordinance of 1785 of dividing the lands by prior survey into six mile square townships, one-half of which were to be further subdivided into sections of one square mile each, and the auction system of sale, were continued. The minimum price per acre was raised to two dollars and a ''Receiver'' provided to take the payments. The improved condition of the nation's credit had rendered this increased price possible. The appointment of a ''Surveyor-General'' to supervise the making of surveys was also authorized. It was his ''duty to engage a sufficient number of skillful surveyors as deputies'' to carry on the public surveys.

An Act of May 10, 1800[9] supplemented the Land Act of 1796, and contained detailed provisions which made the earlier act more workable. Certain land offices were established so that the lands could be purchased more easily locally, and a Register was authorized to enter the applications and perform other clerical duties in cooperation with the Receiver, already provided for under the earlier act. On April 25, 1812[10] a General Land Office was also established and a commissioner provided to take over the executive land duties which had up to that time devolved on the Secretary of the Treasury. The commissioner became the custodian of the books, survey plats, and other public land records at Washington. The General Land Office remained a bureau of the Treasury Department until March 3, 1849, when it was transferred to the newly created Department of the Interior.[11] The surveying of public lands became an administrative act confided to the supervision of the Commissioner of the General Land Office.[12] The importance of this federal public land system is emphasized by the fact that, under its wise provisions, there has been transferred into private ownership the larger part of a great belt of the most fertile and productive land in the entire world, excelling in agricultural crops and manufacturing opportunities as well as in richness and variety of mineral resources. Extending across the temperate zone of a continent and facing on two great oceans, this favored region has, in the comparatively short period of its existence, produced greater wealth and become the home of a people enjoying a higher standard of living than any other region in the history of the human race.

---

[5] United States v. California (1947) 332 U. S. 19, 27; Sinclair v. United States (1929) 279 U. S. 263, 294.

[6] The Secretary of the Treasury had been authorized by Congress "to execute such services relative to the sale of the lands belonging to the United States, as may be by law required of him . . ." (1789) 1 STAT. 65, and Hamilton, as Treasurer, doubtless saw more immediate money coming into the Federal Treasury as the result of the adoption of such a plan.

[7] Congress had already authorized the sale of certain public lands which had been surveyed into townships under the Land Ordinance of 1785.

[8] (1796) 1 STAT. 464.

[9] (1800) 2 STAT. 73.

[10] (1812) 2 STAT. 716.

Federal Land Department Now the ''Bureau of Land Management.'' As has been noted, a Receiver to accept the monies received by the United States for sales of the public lands was authorized in 1785, a Surveyor-General was appointed in 1796, and a Register, to perform the clerical duties of the office, in 1800. The General Land Office with its commissioner in charge in Washington, D.C., was provided in 1812. In 1849 the functions of the land department and the various land officials were transferred from the Treasury Department to the Department of the Interior, and the Secretary of the Interior thereupon assumed control. A Register and a Receiver were appointed for each of the numerous district United States land offices scattered throughout the public land states, and a Surveyor-General was placed in charge of the public land surveys in each state and territory of the growing West. This remained the setup of the land department for over one hundred years until 1921 when the President was authorized to consolidate the offices of Register and Receiver and abolish the office of Receiver.[13] The office of Surveyor-General was abolished in 1925, and the field surveying service was placed under the United States Supervisor of Surveys.[14] District Cadastral Engineers took charge of the maps and records formerly in the custody of the Surveyors-General.

The most radical change of all has recently taken place. Congress passed the ''Reorganization Act of 1945,''[15] authorizing the President to make recommendations to it for the reorganization of various departments of the government under his control. These ''Reorganization Plans'' were approved by Congress December 20, 1945.[16] Among other changes, the functions of the General Land Office and the Grazing Service in the Department of the Interior were consolidated to form a new agency to be known as the ''Bureau of Land Management,'' headed by a Director with an Associate Director and Assistant Directors. The General Land Office, Grazing Service, Commissioner of the General Land Office, all Registers of the district land offices, and the Supervisor of Surveys, together with the Field Surveying Service, then known as the Cadastral

---

[11] (1849) 9 Stat. 395.

[12] Rev. Stat. § 453 (1875); United States v. Morrison (1916) 240 U. S. 192, 210.

[13] (1921) 42 Stat. 208.

[14] (1925) 43 Stat. 1144, 43 U. S. C. § 51 (1940).

[15] (1945) 59 Stat. 613, 5 U. S. C. § 133y (Supp. 1946).

[16] (1946) 60 Stat. 1100, 5 U. S. C. A. § 133y-16 (Supp. 1947).

Engineering Service, were abolished. The Secretary of the Interior was given full authority to administer, direct, and control the "Bureau of Land Management" and to designate officers and agencies to assist him. All records, property, and personnel were transferred for such purposes. As a result, the General Land Office has become the Bureau of Land Management, the Commissioner of the General Land Office is now the Director of the Bureau of Land Management, and the Registers are known as Acting Managers of the District Land Offices.[17] The Grazing Service has become the Division of Grazing, a branch of Range Management. There is also a Regional Cadastral Engineer who has charge of the survey records, and survey of public lands is now done by the Division of Engineering and Construction.

The duties of the Bureau of Land Management are to maintain general supervision, through survey, management, and disposition of the public lands of the United States and their natural resources, in accordance with national conservation laws and policies.[18]

The Public Land Surveys. The preceding historical account of the origin and early beginnings of our public land system is of more than passing interest. This system of public surveys, originating with some of the New England colonies as early as 1730, was, as we have seen, carried forward and embodied in the federal land system and continued down with little change to the present day. Under this system most of the great empire of federal public domain extending to the Pacific Ocean, which the United States acquired by cession from the original states, by purchase from foreign countries, and by treaty and by conquest from Mexico, has been disposed of to settlers and private buyers. This system has certain outstanding advantages. By requiring a public survey of these lands prior to the passage of title to grantees an orderly development of the public domain has resulted. The conflicts of title which inevitably accompany overlapping areas has been largely avoided. The keeping of the official survey notes and plats as public records has facilitated the identification of land boundaries. The method of projecting rectangular surveys has resulted in great simplicity and brevity of land description. The reports required of the public land surveyors, as to the quality of the land surveyed and the existence of known mines, salt springs, timber, bodies of water and water courses, mountains, etc., have brought into these public records a great fund of valuable information:

> Public-land surveys made by the General Land Office result in the official township maps which are the basis of all land titles and to which, therefore, all data on land classification must finally be adjusted. The system now in use was adopted in essentially its present form in 1785. Under this system a certain initial point is first selected through which a north-south line, called a principal meridian, and an east-west line, called a base line, are run. At successive intervals, usually 24 miles, north and south of the base line standard parallels or correction lines are established parallel to the base, and similarly at intervals east and west of the principal meridian guide meridians are established. Because of the convergence of meridians toward the poles

---

[17] Presumably they will eventually be called "managers," but since they had been appointed as "registers" for a definite term of office it was decided that they could not properly be designated as managers. Therefore, for the present they are referred to as "acting managers."

When the writer started the practice of the law, some 50 years ago, there were ten or more district land offices in California. Now there are only two, one in Sacramento and the other in Los Angeles. This is a reflection of the great decrease in the sales of and dealings in public lands. Most of the important and desirable public land has either passed into private ownership or been included in federal reservations.

[18] This statement is substantially the one that appears in a government issued pamphlet containing information on the new setup.

> these guide meridians are not parallel to the principal meridian but approach it toward the north. In order to correct this narrowing the guide meridians are offset at each standard parallel and started anew northward at their original distance apart. The quadrilateral thus defined is subdivided into townships, each approximately 6 miles square, and each township in turn is divided into 36 sections 1 mile square. Each section is further subdivided into quarters, and each of these is held to contain four 40-acre tracts, or quarter-quarters, the smallest commonly recognized legal subdivision of the public-land system. Appropriately marked monuments are set at all township and section corners and at the middle points of the side lines of sections, thus indicating the limits of the quarter sections.[19]

The townships extending in the same line north and south are called ranges, and these ranges are numbered consecutively, both to the east and to the west, beginning with number one immediately on each side of the basic reference point. The tiers of townships extending contiguously east and west are also numbered consecutively, both to the north and to the south, commencing with the same basic reference point. While, as originally adopted, the system of public land surveys contemplated leaving each alternate township without further subdivision, the division of all townships into sections of one square mile each was soon authorized. Section 1 is the extreme upper right hand or northeasterly square mile of the township. The sections are numbered consecutively 1, 2, 3, 4, 5, 6, reading to the left or west and extending in a row along the north side of the township, and then dropping down one tier they are numbered 7, 8, 9, 10, 11 and 12, extending to the right or east. This system of numbering alternates as above indicated is continued until the bottom row of sections in the township is reached; section 36 becomes the last or most southeasterly section of the township.[20] A section is treated as being divided into four equal parts of 160 acres each. These quarter sections are still further divided, theoretically, into 40 acre square tracts for the purposes of agricultural disposition, and for the making of placer mining locations the sections may be divided into still smaller square tracts of ten acres each.[21]

Public Surveys and Resurveys. No system is perfect, and this method of checkerboarding the vast areas of federally owned land had its inevitable shortcomings. The establishment of basic reference points, most of which were natural features such as mountain tops,[22] from which to start the township surveys in any particular region necessarily resulted in the creation of tiers of fractional townships along the zones of meeting of surveys extending out toward each other from the nearest basic reference points. Since these were usually arbitrarily selected natural features, it was inevitable that surveys emanating from each would not harmonize where they met. Errors in measurement due to incompetent surveyors or faulty instruments also resulted in serious discrepancies, and much litigation to straighten out conflicting surveys and claims has resulted. Worst of all, gross survey frauds were perpetrated on the government. In many instances little if any survey work was actually done in the field; perhaps only a few of the more accessible and prominent corners were established, and those inaccurately. "Paper" field notes were written up in an office with mere guesses as to topography, stream crossings, and character of land. Public scandals arose and criminal proceedings resulted.[23] Wherever these conditions have been found to exist the government has usually ordered actual surveys or resurveys made to remedy these deficiencies. In making such "corrective" surveys of public lands, the federal government may not interfere with already vested rights to any of the lands involved:

---

[19] THE CLASSIFICATION OF THE PUBLIC LANDS, BULL. 537, U. S. GEOLOGICAL SURVEY 61.

[20] (1796) 1 STAT. 464.

[21] (1891) 26 STAT. 1097, 30 U. S. C. § 36 (1940); 2 LINDLEY, MINES § 448 (3rd ed. 1914).

[22] In California the Mt. Diablo Meridian governs public land surveys of all central and northern California and the entire state of Nevada; the San Bernardino Meridian governs surveys in southern California and the Humboldt Meridian, surveys in northwest California west of the Coast Range. DONALDSON, *op. cit. supra* note 1 at 181.

> Although the power to correct surveys of the public land belongs to the political department of the Government and the Land Department has jurisdiction to decide as to such matters while the land is subject to its supervision and before it takes final action, *Cragin v. Powell*, 128 U.S. 691, 698; *Knight v. Land Association*, 142 U.S. 161, 177; *Kirwan v. Murphy*, 189 U. S. 35, 54, this power of supervision and correction by the Department is 'subject to the necessary and decided limitation' that when it has once made and approved a governmental survey of public lands, and has disposed of them, the courts may protect the private rights acquired against interference by corrective surveys subsequently made by the Department. *Cragin v. Powell, supra*, p. 699. A resurvey by the United States after the issuance of a patent does not affect the rights of the patentee; the Government, after conveyance of the lands, having 'no jurisdiction to intermeddle with them in the form of a second survey.' *Kean v. Canal Co.*, 190 U. S. 452, 461. And although the United States, so long as it has not conveyed its land, may survey and resurvey what it owns, and establish and reestablish boundaries, what it thus does is 'for its own information' and 'cannot affect the rights of owners on the other side of the line already existing.' *Lane v. Darlington*, 249 U. S. 331, 333.[24]

A prior purchaser may assert whatever title he has acquired under the original survey as against anyone claiming under the resurvey,[25] and the original survey may not be collaterally attacked.[26]

It has been held, however, that an Act of Congress authorizing a resurvey of public lands is a legislative declaration that the lands are to be regarded as unsurveyed and that the *future* disposition of the lands is to be regulated by the new survey.[27] The making and correction of public land surveys belong to the political department of the government, and it may make a resurvey of lands where the boundaries are in dispute even after first refusing to do so.[28]

The Classification of Public Lands as to Character. Judge Lindley has stated that there had been "no general systematic classification of the public lands, according to their mineral or nonmineral character, for purposes of sale or disposal . . ." [29] However, he qualified this by adding "at least until a very recent period." As a matter of fact, at the time that his comment was written, the United States Geological Survey, under instructions from the Department of the Interior, had entered upon an active and far-reaching program of land classification. This had been brought about by the government's awakened interest in conservation of its natural resources, which had received much impetus during the Theodore Roosevelt administration after the turn of the century.

---

[23] The so-called "*Benson* cases" arising in California are outstanding example. United States v. Perrin (1889) 131 U. S. 55; United States v. Hall (1889) 131 U. S. 50; United States v. Benson (C. C. A. 9th 1895) 70 Fed. 591. The government has abandoned this system of letting out the surveying of public lands on a contract basis and the work is now done by government surveyors in the Division of Engineering and Construction.

[24] United States v. State Investment Co. (1924) 264 U. S. 206, 212.

[25] Greene v. United States (C. C. A. 5th 1921) 274 Fed. 145.

[26] Phelps v. Pacific Gas and Electric Co. (1948) 84 A. C. A. 284, 287, 190 P. (2d) 209, 212. In this case the original survey was held to be inaccurate, but not fraudulent. *Id.* at 280, 190 P. (2d) at 213.

[27] Cox v. Hart (C. C. A. 9th 1921) 270 Fed. 51.

[28] United States v. Redondo Development Co. (C. C. A. 8th 1918) 254 Fed. 656.

[29] 1 LINDLEY, MINES § 102.

While Judge Lindley's comment was true as to any extensive mineral and nonmineral classification of lands of the public domain as of that time, there had been a rather careful examination and classification of railroad lands, which were odd numbered sections embraced within the railroad grants which Congress had made to encourage the building of railroads into the vast, then largely uninhabited public domain. These grants invariably excepted mineral lands from their operation and in many instances, especially where railroads penetrated the fabulously rich mineral bearing lands of the West, it became necessary to classify these grants with respect to their mineral or nonmineral character. The same has been true of certain lands set aside as Indian Reservations.[30] Another outstanding example of classification of public lands was of their forested areas, which were withdrawn from private entry and created into permanently segregated areas, at first called "Forest Reserves," now known as "National Forests."[31] Vast areas of public domain were also classified as coal, oil, and gas bearing lands and withdrawn under presidential order,[32] which action received subsequent confirmation from Congress.[33]

Public lands valuable for phosphates, potash, and other strategic minerals have from time to time been classified and withdrawn from private entry.[34] Recently lands containing deposits of uranium bearing ores have been withdrawn from entry because of the public interest in atomic energy.[35]

United States Geological Survey. The United States Geological Survey,[36] acting under the Department of the Interior, now has charge of land classification,[37] and issues topographic maps, geological bulletins, and monographs descriptive of mines and mineral resources. This valuable work is not confined to the public domain but extends to all of the mineral bearing regions of the United States, whether in private ownership or not.[38]

Classification of public lands has usually preceded and been directed at eventual withdrawal from private acquisition, with a view to reservation in the public interest. Since metalliferous lands are not, as a general rule, subject to withdrawal, their classification has had other objects in view.[39] There have also been attempts at various times to induce Congress to withdraw metalliferous lands from outright disposition and place them in a state of permanent reservation, subject only to leasing from the federal government. However, the practice initiated by the pioneer miners

---

[30] BULL. 537, *supra* note 19 at 143.

[31] This was done by presidential proclamation pursuant to various Acts of Congress. *E.g.*, (1891) 26 STAT. 1095.

[32] The validity of such withdrawals without prior congressional authorization was upheld in United States v. Midwest Oil Co. (1915) 236 U. S. 459; Colby, *The Law of Oil and Gas* (1942) 30 CALIF. L. REV. 245, 255.

[33] (1910) 36 STAT. 847, 43 U. S. C. § 142 (1940); (1911) 36 STAT. 1015, 30 U. S. C. § 103 (1940); (1912) 37 STAT. 497, 43 U. S. C. § 142 (1940).

[34] Colby, *Mining Law in Recent Years* (1945) 33 CALIF. L. REV. 368, 376.

[35] See Atomic Energy Act of 1946, 60 STAT. 755, 42 U. S. C. A. § 1801 (Supp. 1946). The Atomic Energy Commission has offered bonuses in cash for the discovery of uranium ores and fixes the price at which these ores are purchased by the government.

[36] Created March 3, 1879, 20 STAT. 394, 43 U. S. C. § 31 (1940).

[37] At one time land classification was conducted by special commissioners, but the United States Geological Survey has more recently been given charge of this work.

[38] THE CLASSIFICATION OF THE PUBLIC LANDS, *supra* note 19, issued by the United States Geological Survey, is an excellent and comprehensive treatment of this subject. It details the methods of land classification adopted by the Survey and the various types of lands that have been or are being classified.

[39] *Id.* at 143.

"in the roaring days of '49," long prior to any Congressional confirmation of their self-asserted "miners' customs, rules and regulations,"[40] of free mining on the public domain has become so strongly entrenched that it would be difficult now, after successful operation for a full century, to overturn this system created by the miners themselves to fit their own needs.[41]

State Geological Surveys. Not only does the federal government make these valuable geological surveys of the federal public lands and also of important mining districts, including mines in private ownership, but most of the western or mining states have geological surveys of their own which cooperate with the federal agency. Outstanding in this respect is California.[42] The California mineral surveys and publications are the work of the Division of Mines in the Department of Natural Resources.[43]

Spanish and Mexican Grants.[44] The oldest grants of land that affect the public domain are grants to private individuals within the large public land areas which the United States acquired from Spain, France, and Mexico by purchase, cession and conquest. These prior grants made by these predecessor sovereign governments have given rise to many complex legal questions of a most interesting nature.[45] The law of nations, to which the United States has given full sanction, provides that all such legitimate private claims shall be recognized by any nation succeeding to sovereignty over such newly acquired areas. The duty of providing a mode for securing and establishing French, British, Spanish and Mexican[46] land titles and fulfilling treaty obligations devolved upon the political branch of the government. The obligations are political in character, to be discharged in such manner and upon such terms as the United States deems expedient to conform to treaty requirements.[47] Congress could either discharge that duty itself, delegate it to the courts, with the inevitable delays and confusion affecting land titles in a vast annexed area,[48] or create special administrative tribunals from whose determinations appeals to the regularly constituted courts might be had.[49] Some grants were confirmed by direct action of Congress, and the legality of such grants is not subject to review by the courts.[50] Where Congress has confirmed these private claims by special enactment, no issuance of a formal patent is required as evidence of the grant,[51] and a tribunal subequently created by Congress is without power to determine conflicting rights to such lands.[52]

---

[40] The earliest direct and positive confirmation is found in (1866) 14 STAT. 251; see Colby, *supra* note 34 at 370-374.

[41] The Mining Act of 1872, 17 STAT. 91, 30 U. S. C. § 22 (1940), has remained the basic law of mines to this day as far as metalliferous deposits of the public domain are concerned. One potent underlying reason for retaining this self-initiated system is because the search for and discovery of metalliferous ore deposits have been largely accomplished by the pioneer prospector. Unless he is appropriately rewarded by being able to acquire exclusive title to the object of his search, usually made in rugged mountainous and arid desert regions, the chief incentive for his expenditure of effort would be gone. Because some such incentive has seemed essential, in all parts of the world throughout the ages special inducements have been given prospectors and miners so that they may profit by their discoveries. 2 LINDLEY, MINES § 335.

[42] California as early as 1860 appointed Josiah Dwight Whitney State Geologist to make a geological survey of the state, including its minerals. (1860) CAL. STAT. 225. Professor Whitney and his corps of able assistants did some fine geological work, the results of which were published in a volume entitled GEOLOGY (1865).

[43] The writer is indebted to Mr. Olaf P. Jenkins, Chief of the Division of Mines, Ferry Building, San Francisco, for the following information on this subject. The Chief of the Division is known as the State Mineralogist, and the general policies of the Division are determined by a State Mining Board consisting of five members. The Division carries on cooperative work with the United States Geological Survey in the detailed mapping of mineral areas, the results of which are published by the Division, which also issues a *California Journal of Mines and Geology* and monthly circulars containing valuable mineral information of general interest. The Division has an extensive mining library and mineral collection at its headquarters in San Francisco and cooperates most effectively and efficiently with the mineral industry of California. For further information as to the work and activities of the Division of Mines, see CAL. PUB. RESOURCES CODE §§ 2200-2210.

[44] This subject has been discussed in 1 LINDLEY, MINES §§ 113-128.

[45] TREAT, *op. cit. supra* note 1, c. IX.

[46] Some of these land claims and the circumstances surrounding their initiation were of a highly romantic character, and much in our literature has been written on the subject of haciendas, ranchos, pueblos and missions. Many of these private claims involved areas that were principalities in size and value. As might be expected, because of the large financial inducements there were numerous applications for confirmation of title based on forged and fraudulent documents.

[47] *See* United States v. O'Donnell (1938) 303 U. S. 501, 504, 510-511; Borax, Ltd. v. Los Angeles (1935) 296 U. S. 10, 15, 19.

Congress created special tribunals and boards of commissioners empowered to take evidence and determine the extent and validity of certain classes of grants and to authorize issuance of patents therefor. These patents and the final decrees on which they are based are conclusive between the United States and the claimants but do not affect the interests of third persons.[53] The Statute of Limitations of 1891 bars the United States from bringing suit to set aside land grant patents of this character.[54]

After the tribunal or commission has adjudicated a claim and authorized issuance of a patent it is too late for another party to assert adverse title.[55] These titles, though required to be confirmed by a United States tribunal, are titles originating from and relating back to the date of the original grant.[56]

Many of these grants by foreign sovereigns were far from ''complete and perfect,'' but, on the contrary, were vague and indefinite in description and irregular in outline. In such cases, particularly when ''floats'' were involved, surveys were necessary to locate the grants definitely on the ground.[57] Where, because of indefinite description, it became necessary to survey a grant, the title relates back to the date of the survey, even though the United States did not issue a confirmatory patent until many years later.[58]

Where the grants are inherently defective or difficult of determination they constitute an ''imperfect obligation'' and affect ''only the conscience of the new sovereign,'' from which on confirmation they receive ''a vitality and efficacy which they did not before possess.'' Their validity results ''wholly from the act of confirmation and not from any French or Spanish element which entered into their previous existence.'' Hence, the usual doctrine of relation back to the foreign grant does not apply.[59]

---

[48] United States v. O'Donnell, *supra* note 47 at 511, 515; Borax, Ltd. v. Los Angeles, *supra* note 47 at 19-21; Knight v. United States Land Assn. (1891) 142 U. S. 161, 216.

[49] United States v. O'Donnell, *supra* note 47 at 512, 524.

[50] Yeast v. Pru (D. N. M. 1923) 292 Fed. 598, 605. In this case the congressional confirmation of grants of land to towns was held to be to the towns as communities and not to the idividual claimants. *Id.* at 604. A case where the grant was held to be a private grant as distinguished from a community grant is Chadwick v. Campbell (C. C. A. 10th 1940) 115 F. (2d) 401. See also Reilly v. Shipman (C. C. A. 8th 1920) 266 Fed. 852, 858; Laurel Hill Cemetery Assn. v. All Persons (1945) 69 Cal. App. (2d) 190, 192-193, 158 P. (2d) 759, 760 (involving title to a portion of the Pueblo of San Francisco, the pueblo title having been confirmed by direct act of Congress (1866) 14 Stat. 4); 1 Lindley, Mines § 126. Pueblo rights are considered in Lane v. Pueblo of Santa Rosa (1919) 249 U. S. 110; Pueblo of Santa Rosa v. Fall (App. D. C. 1926) 12 F. (2d) 332.

[51] Reilly v. Shipman, *supra* note 50.

[52] La Joya Grant v. Belen Land Grant (1916) 242 U. S. 595, 598.

[53] United States v. O'Donnell, *supra* note 47 at 512-513; United States v. Coronado Beach Co. (S. D. Cal. 1919) 274 Fed. 230; Watts v. Ely Real Estate Inv. Co. (D. Ariz. 1919) 254 Fed.862 . These specially constituted tribunals had jurisdiction of Mission lands also. Hogan v. United States (C. C. A. 9th 1934) 72 F. (2d) 799.

[54] Hogan v. United States, *supra* note 53.

[55] Romero v. Janss Inv. Corp. (C. C. A. 9th 1936) 84 F. (2d) 832.

[56] United States v. O'Donnell, *supra* note 47 at 513-514; United States v. Coronado Beach Co. (1921) 255 U. S. 472, 488; Commodores Point Terminal Co. v. Hudnall (S. D. Fla. 1925) 3 F. (2d) 841, 843.

[57] Jones v. St. Louis Land Co. (1914) 232 U. S. 355, 363; United States v. Redondo Development Co., *supra* note 28.

[58] Sanchez v. Deering (C. C. A. 5th 1924) 298 Fed. 286, *aff'd* (1926) 270 U. S. 227; see also Wilson Cypress Co. v. Del Pozo (1915) 236 U. S. 635, 651.

A United States patent issued upon a confirmed Mexican grant is regarded as a quitclaim deed from the United States, relating back to the time when the petition for confirmation was filed with the tribunal created to adjudicate the claim, and as a record of the federal government showing its judgment with respect to the title of the patentee at the date of the cession.[60]

The owner of a Mexican grant perfected before the cession under the Gadsden purchase was permitted, but not required, by Act of Congress to assert his claim. A failure to do so in no way affects the validity of his title.[61]

Congress, in many instances, has provided by special enactment for the determination of certain Mexican grants which were in the nature of ''floats,'' giving the grantee the right to select a specified area of land from the main body of public land. Usually such legislation provided that the lands selected should be nonmineral, but this has been interpreted to prohibit merely the selection of ''land then known to contain mineral'' and not to render the grant nugatory by reason of any future discoveries of minerals.[62]

Water boundaries create situations which are in many instances difficult of solution where title to upland is involved. Foreign land grants bordering on bodies of water are no exception in this respect. While, as a general rule, upon the acquisition of the territory from Mexico the United States acquired the title to tide lands[63] with the title to upland, but held the tide lands in trust for the future states that might be erected out of that territory, there is an established qualification that this principle is not applicable to tide lands which had previously been granted by Mexico to private parties under a different method of disposition. The rights of such grantees were dependent upon Mexican laws, and as owner of the tide lands as well as the uplands, Mexico had power to place the boundaries wherever she thought proper.[64] In some instances these Mexican grants described the lands as including the tide lands and extending to the deep water line or ''anchorage for ships,'' the usual boundary limit in this country.[65]

---

[59] Jones v. St. Louis Land Co., *supra* note 57 at 362.

[60] Ely Real Estate & Investment Co. v. Watts (C. C. A. 9th 1920) 262 Fed. 721, 722, 726.

[61] *Id.* at 726.

[62] *See* Lane v. Watts (1914) 234 U. S. 525, 527, 539, *reh'g. denied* (1914) 235 U. S. 17. The latter citation discusses conflicts of Mexican grants with each other, as does also La Joya Grant v. Belen Land Grant (1916) 242 U. S. 595. Lane v. Watts also holds that title to a floating grant vested by survey of its location and that approval could not subsequently be divested by the Land Department. The action of the commissioner of the General Land Office in making such approval could not be revoked by his successor in office. Lane v. Watts, *supra* at 540. See also Ballinger v. Frost (1910) 216 U. S. 240 and Dahl v. Raunheim (1889) 132 U. S. 260.

[63] The great legal battle over the tide lands which has resulted in a decision declaring the United States to be their owner (United States v. California (1947) 332 U. S. 19) is in the minds of everyone. Two justices dissented, and one did not participate. This decision apparently has reversed a great body of authority *contra,* which had been built up largely by the Supreme Court itself. It is worth noting that as careful a student and exponent of the law as Judge Lindley, who had specialized on the law of waters as well as of mines, had concluded: "There is no principle involved in the consideration of the public land system better settled or more clearly enunciated than that lands under tidal waters, and below the line of ordinary high tide are not 'public lands.' When a state bordering upon these waters is admitted to the union it becomes, by virtue of its sovereignty, the owner of all lands extending seaward . . . to the distance of three miles, or a marine league." 2 LINDLEY, MINES § 429.

The reaction resulting from this decision of the Supreme Court upsetting the rule which Judge Lindley had considered so positively settled has been so profound that there is a bill pending before Congress intended to remedy this radical upset and to confirm in the states the title to tide lands which it had previously been generally assumed they owned. This subject will be more fully treated hereafter under its appropriate heading.

A case which is outstanding because it was contested so bitterly and because the government had such a vital interest in the outcome, is *United States v. O'Donnell,*[66] involving tide and marsh land contiguous to the great naval yard at Mare Island, Solano County, California. In 1841 Alvarado, Mexican Governor of California, granted to Castro the Island, La Yegua (Mare Island), and the United States succeeded to this Mexican title by purchase under authorization of Congress.[67] Opposing parties claimed under a patent issued by California in 1857 which purported to convey the area in question as swamp and overflowed lands under the Swamp Lands Act of Sept. 28, 1850.[68] The Court held that, even though the Secretary of the Interior had found the lands to be swamp lands within the meaning of the Swamp Lands Act and had certified them as such as the result of a mandamus proceeding[69] compelling him to do so, this did not bind the United States and preclude a subsequent determination of the respective rights of the rival claimants. The Court decided that the Mexican grant title included the area in controversy and that it was superior to the swamp land title emanating from the State of California.[70] The Supreme Court reasoned that, at the date the Swamp Lands Act of 1850 became effective, this swamp land was not a part of the public domain because it had already been disposed of under a title that the United States had assumed a political obligation to recognize and respect. The fact that the Swamp Lands Act antedated the Mexican Claims Act, and the confirmation of claims under it, was held to be immaterial, for the Swamp Lands Act was subject to the treaty obligations of the United States. The description in the Mexican grant was also held to be inclusive enough to embrace the adjacent marsh land as well as the Mare Island upland.

An unusually complicated case arose because of the physical agency known as ''avulsion,'' where land boundaries are suddenly changed by the action of water (as opposed to accretion, which is an imperceptible building up and adding to land areas, or to reliction or erosion, which is the gradual retreat of a land boundary). The course of the Rio Grande had changed suddenly, resulting in large land areas known as "bancos" being cut from Mexico and added to the Texas side of the river. The opposing litigants had titles granted by their respective governments.[71] The Texas title prevailed, largely as the result of the provisions of treaties between the United States and Mexico settling questions of jurisdiction and sovereignty over such "banco" lands as had been affected by avulsive changes.[72]

---

[64] Borax, Ltd. v. Los Angeles (1935) 296 U. S. 10, 15, 20. See also City of Los Angeles v. Borax Consolidated Ltd. (C. C. A. 9th 1935) 74 F. (2d) 901, 903, and United States v. Coronado Beach Co., *supra* note 53.

[65] United States v. Coronado Beach Co., *supra* note 56 at 487-488.

[66] *Supra* note 47.

[67] (1852) 10 STAT. 100, 104.

[68] (1850) 9 STAT. 519.

[69] Work v. United States (App. D. C. 1927) 23 F. (2d) 136.

[70] The swamp land claimants had originally applied to the Land Department for issuance of a patent confirming their swamp land title from the state, and the Secretary of the Interior found the land to be of that character. Suit was brought to compel him to certify to this fact, and the Supreme Court of the District of Columbia issued its peremptory writ of mandamus. This action was sustained on appeal. Work v. United States, *supra* note 69. The United States brought suit in the local federal district court in California for cancellation of the swamp land patents, and the trial court sustained the United States. On appeal this decision was reversed in O'Donnell v. United States (C. C. A. 9th 1936) 91 F. (2d) 14, with one judge dissenting. The Supreme Court granted certiorari and sustained the trial court, U. S. v. O'Donnell, *supra* note 47. Other cases which involved these same titles are Sawyer v. Osterhaus (N. D. Cal. 1914) 212 Fed. 765; Bouldin v. Phelps (C. C. N. D. Cal. 1887) 30 Fed. 547; San Francisco Sav. Union v. Irwin (C. C. D. Cal. 1886) 28 Fed. 708, *aff'd,* (1890) 136 U S. 578.

Mines within the foreign grants were invariably held to be a part of the areas granted and not subject to special disposition as mineral lands. The outstanding case of this character in California involved the "Mariposa Grant," originally made to Alvarado in 1844 and confirmed to his grantee, the colorful General Fremont, for "ten square leagues" of land in what is now Mariposa County, an area containing many valuable gold mines.[73]

Another historic case which arose in California involved title to the famous New Almaden quicksilver mine, situated in Santa Clara County and discovered in 1845 while Mexico still had jurisdiction. This case was bitterly contested because of the great value and unique character of the mine.[74] A divided court held that the mining claimant did not have a valid title under the mining laws of Mexico because no officials to accept mine filings, required by the Spanish-Mexican mining law, had ever been appointed in California. The United States was the contesting party and attacked Castillero's claim to the mine on the theory that under the law of Mexico the sovereign had, under the doctrine of regalian rights, automatically reserved the mining title out of the large grant of agricultural land which included the mine. If Castillero's title to the mine failed, it was contended the mine would belong to the new sovereign, the United States. However, Judge Field, speaking for the Supreme Court of California, later held [75] that the doctrine of regalian rights to mines was foreign to the land laws of the United States. The Supreme Court of California had much earlier erroneously held that [76] the state had succeeded to Mexico's regalian rights to mines.

The settlement of title to these Spanish and Mexican grants in California was brought about only after protracted litigation during the first fifty years of California's statehood. It proved a boon to the lawyers of those days, who collected some of the largest fees in money or percentage of the land involved ever received for legal services.

These grant surveys have naturally complicated the rectangular system which was being extended throughout the public domain as rapidly as circumstances would warrant and which had to be fitted into these usually irregular grant boundaries. This has resulted in the creation of fractional subdivisions of public land wherever the rectangular public land surveys have abutted on the exterior boundaries of such irregular shaped prior grants and gives some suggestion of the confusion which would have existed had Congress adopted the system of irregular surveys and ''indiscriminate locations.''

---

[71] Texas and not the United States had issued the patent to the Texas claimant, because Texas joined the Union as a sovereign and independent state, and, consequently, Texas and not the United States owned all the public land within its borders.

[72] Willis v. First Real Estate & Inv. Co. (C. C. A. 5th 1934) 68 F. (2d) 671.

[73] Fremont v. United States (U. S. 1854) 17 How. 541. While Judge Lindley had dealt fully with this and the following case here discussed (1 LINDLEY, MINES § 125), they are deemed of sufficient importance and interest to note briefly here. It will interest some of the readers of this review to note that this case was successfully argued for Fremont in Washington, D. C., by Mr. William Carey Jones, father of the Dean, of the same name, who organized the Law School at the University of California.

[74] United States v. Andreas Castillero (U. S. 1862) 2 Black 17. Over 350 pages of that Report is devoted to it. Some of the most eminent lawyers of the time, including Hall McAllister, were counsel.

[75] Fremont v. Flower (1861) 17 Cal. 199.

[76] Hicks v. Bell (1853) 3 Cal. 219.

Land Grants to States.[77] From the very outset, the federal government has evinced a policy of liberality in its grants of public lands to the states. These grants have been mainly for school and educational purposes. The Land Ordinance of May 20, 1785, enacted by the Continental Congress, provided that ''lot'' (later named ''section'') number 16 of each township should be reserved for the maintenance of public schools within the township.[78] Congress, in 1848, added section 36 of each township to grants to newly erected states [79] and later, in certain instances, added other sections.[80] These grants were, with few exceptions, for educational aid. Where private rights had already attached to any portions of the designated ''school'' sections or they were proven to be mineral in character at the date the grant would take effect, or the federal government had already reserved the land for other purposes, the right to select an equivalent area of public land as indemnity or lieu land to compensate for such loss was provided for by Congress. Congress has also, on various occasions, made additional grants of large acreages of unidentified public lands to be thereafter selected, the proceeds to be devoted in some cases to internal improvements and in others to the support of agricultural colleges. The total of these state land grants constitutes one of the largest dispositions of federal public lands for a single objective. This ''legislation of Congress designed to aid the common schools of the States is to be construed liberally rather than restrictively.'' [81]

The case of *United States v. Sweet* [82] considered the question as to whether Congress intended that mineral lands should be excepted from the grants of school lands to the western or mining states. The reasoning of this case may be summarized as follows: In its legislation concerning the public lands, Congress has, on various occasions, made a distinction between mineral lands and other lands, dealing with them along different lines and withholding mineral lands from disposal save under special laws. This policy was given particular emphasis following the discovery of gold in California in 1848, as evidenced by the mineral reservations contained in the Homestead Act, the railroad grants, and other land grants of that period. These declarations and reservations were the expression of the will of Congress that all public land grants should reserve and exclude mineral lands, in the absence of an otherwise expressed intention.[83]

---

[77] This subject is found treated in 1 LINDLEY, MINES §§ 132-145.

[78] Commenting on this policy the Supreme Court of the United States has said: "The practice of setting apart section No. 16 of every township of public lands, for the maintenance of public schools, is traceable to the ordinance of 1785, being the first enactment for the disposal by sale of the public lands in the Western territory. The appropriation of public lands for that object became a fundamental principle, by the ordinance of 1787, which settled terms of compact between the people and States of the northwestern territory, and the original States, unalterable except by consent. One of the articles affirmed that 'religion, morality, and knowledge, being necessary for good government and the happiness of mankind'; and ordained that 'schools, and the means of education, should be forever encouraged.' This principle was extended, first, by congressional enactment, (1 Stats. at Large, 550, § 6,) and afterwards, in 1802, by compact between the United States and Georgia to the southwestern territory . . . .

". . . the constancy with which the United States have adhered to the policy in the various compacts with the people of the newly-formed States, and the care which congress has manifested to prevent the accumulation of prior obligations which might interrupt it, fully display their estimate of its value and importance. There is, obviously, a definite purpose declared to consecrate the same central section of every township of every State which might be added to the federal system, to the promotion 'of good government and the happiness of mankind,' by the spread of 'religion, morality, and knowledge,' and thus, by a uniformity of local association, to plant in the heart of every community the same sentiments of grateful reverence for the wisdom, forecast, and magnanimous statesmanship of those who framed the institutions for these new States, before the constitution for the old had yet been modelled." Cooper v. Roberts (U. S. 1885) 18 How. 173, 177-178.

[79] TREAT, *op. cit. supra* note 1 at 277-278.

[80] Sections 2 and 32 in addition to 16 and 36 were granted in a number of instances.

[81] Wyoming v. United States (1921) 255 U. S. 489, 508.

[82] (1918) 245 U. S. 563, *reversing* Sweet v. United States (C. C. A. 8th 1915) 228 Fed. 421.

By Act of March 3, 1853 [84] Congress granted to the State of California sections 16 and 36 in each township for school purposes and a large acreage of public land for other purposes. Mineral lands were not specifically referred to in the grant of school sections, but were expressly excepted from the other grant. In spite of this failure to specifically except mineral lands in the grant of school sections, the Court concluded "that Congress did not intend to depart from its uniform policy in this respect . . . ." [85]

Subsequently, from 1864 to 1873, Congress passed a series of acts dealing with all phases of the acquisition of mineral lands.[86] Thus, the policy of disposing of mineral lands only under laws specifically including them became even more firmly established. It was still further evidenced by the Act of February 28, 1891,[87] which provided that, where sections 16 and 36 were mineral land, the state might select other public lands of equal acreage in lieu thereof. The court in the *Sweet* case concluded that the school grant to Utah of sections 2, 16, 32 and 36 of each township should be similarly construed and that mineral lands in those sections had by implication been excluded from the grant, even though Congress had made no explicit exception of mineral land in the granting act.[88]

Another case of importance, *Work v. Louisiana*,[89] which discussed a somewhat similar situation, involved land claimed under a grant of swamp and overflowed lands to the State of Louisiana by the federal Acts of 1849 and 1850. The claim of title by the state under this grant was contested by the Secretary of the Interior, acting in behalf of the United States, on the theory that the lands were mineral in character and hence title could not pass to the state because the lands were automatically excepted from the grant. The court, however, distinguished this case from *United States v. Sweet,* principally on the ground that "there was no settled public policy in reference to the reservation of mineral lands prior to these granting acts of 1849 and 1850," and hence there was no substantial reason for reading a mineral reservation into these broad and unrestricted grants of swamp and overflowed lands to the state.[90]

---

[83] This policy is codified in REV. STAT. §§ 2318, 2346 (1875), 30 U. E. C. §§ 21, 50 (1940).

[84] (1853) 10 STAT. 244.

[85] Mullin v. United States (1886) 118 U. S. 271; Mining Co. v. Consolidated Mining Co. (1880) 102 U. S. 167.

[86] (1864) 13 STAT. 343; (1865) 13 STAT. 529; (1866) 14 STAT. 251; (1870) 16 STAT. 217; (1872) 17 STAT. 91; (1873) 17 STAT. 607. These and subsequent acts have been codified in 30 U. S. C. (1940), MINERAL LANDS AND MINING.

[87] (1891) 26 STAT. 796, 43 U. S. C. § 851 (1940).

[88] *Supra* note 82 at 572-573. See also State of Utah v. Work (App. D. C. 1925) 6 F. (2d) 675, 676 and People v. Dorr (1945) 68 Cal. App. (2d) 792, 157 P. (2d) 859. It is interesting to note that the case of Cooper v. Roberts (U. S. 1855) 18 How. 173, which had early decided that title to part of a school section 16 in Michigan which was known to be mineral nevertheless passed to that state because the act contained no mineral exception, was held to be distinguishable on the very logical ground that when the grant of school lands to Michigan was made (March, 1847) "the public policy respecting mineral lands had not been expressed in general and permanent laws." United States v. Sweet, *supra* note 82 at 573-574. See also Dunbar Lime Co. v. Utah-Idaho Sugar Co. (C. C. A. 8th 1926) 17 F. (2d) 351, 353, which states that the case of United States v. Sweet has settled this question as far as the western or mining states are concerned.

[89] (1925) 269 U. S. 250.

Another school section case which arose in Utah involved the Coal Land Law and the Leasing Act of 1920. Application had been made to the United States Land Office to purchase certain coal land included in a school land grant section. The lands had been reported by the surveyor as nonmineral and hence the state had sold and issued its patent for them. It had been the rule of the Federal Land Office to treat mineral applications to purchase school land as a contest of the state's right to such lands. While this contest was pending the Federal Leasing Act of 1920[91] had been enacted, providing for the leasing instead of outright disposal of certain mineral lands, including coal lands. The applicant to purchase the coal land contended that by his filing he had acquired a right which could not be abrogated by the subsequent passage of the Leasing Act, but the Supreme Court held that he had acquired no legal status other than that of a contestant and that "so nebulous and insubstantial a claim," which might never come to fruition, "presented no obstacle to the withdrawal of the privilege by the United States."[92] Where there is an application to purchase a school section as "known coal land" at the date of the school grant, the applicant in order to except this land from the operation of the grant must prove that either a coal mine has been opened on said land or coal produced therefrom.[93]

Congress adopted a different policy with respect to lands in Oklahoma. In the Act of 1906,[94] providing for its admission into the Union, the right of the state to receive mineral lands under the grants to it for school and other purposes was distinctly recognized—"a thing not permitted to a state where mining laws are in force."[95]

In most of these grants of school lands to the states, Congress, while specific as to the purpose for which the land was granted, left to the legislatures of the states full power and authority to determine how the granted lands were to be disposed of, whether by sale or lease, and how any revenues derived from such disposition were to be devoted to the interests of the public schools. A very few of the states early adopted a policy of reserving title to these lands and leasing them, the rentals and royalties to be devoted to the upkeep of the schools. This foresighted plan has resulted in a constant and increasing income from this source in those states.

---

[90] The Court emphasizes the fact that swamp and overflowed and not school lands were involved, but there would seem to be no valid basis for invoking such distinction. The case of Cooper v. Roberts (U. S. 1855) 18 How. 173, 179-180, is also relied on by the court as authority for its announcement that, until Congress had adopted a definite policy of placing mineral lands in a separate category for purposes of disposition and had legislated accordingly, a grant of school lands to a state would not be ineffective merely because the particular lands in question were known to be mineral in character.

[91] (1920) 41 STAT. 437, 30 U. S. C. § 181 (1940).

[92] Work v. Braffet (1928) 276 U. S. 560, 565-566, *reversing* (App. D. C. 1927) 19 F. (2d) 666. This decision is cited in Shores v. Utah (1928) 52 Land Dec. 503, 504-505. See also State of Utah (1931) 53 Land Dec. 365, 368.

[93] New Mexico v. Lane (1917) 243 U. S. 52, 55.

[94] (1906) 34 STAT. 267.

[95] Oklahoma v. Texas (1922) 258 U. S. 574, 601. There were two exceptions to the Oklahoma policy, each confined to a limited area. *Id.* at 601.

In most of the states, however, there was a mad political scramble to purchase these school lands outright, and they were sold for a mere pittance of the amounts that could have been realized had a wise and conservative plan of disposal been adopted. Many a scandal resulted, so that in 1910, when Arizona and New Mexico were admitted to the Union, Congress, to make sure that these school lands would be more wisely administered, adopted a new policy which found expression in the enabling act for these states. It was declared that lands granted and confirmed to these states shall be held in a continuing trust and be disposed by lease[96] or sale to the highest bidder at public auction. The proceeds were also to be treated as trust funds.[97] Since the grant, though made in trust, has been made by the general government in its sovereign capacity to the state in the exercise of its sovereign capacity, the matter rests solely in the good faith of the state, and the manner in which the state invests these trust funds may not be questioned or controlled in a suit brought by a private citizen.[98] The state holds and disposes of these school grant lands in its governmental, as distinguished from its proprietary, capacity.[99]

In a suit brought by the United States,[100] which, having created the trust, was in a position to question its proper administration, it was held not to be any violation of the trust provisions to meet expenses incurred in the execution of the trust out of funds belonging to the trust.

A state does not hold these lands as an instrumentality of the United States but in its own right, in trust, however, for the schools of the state. It may tax these lands when sold to a private purchaser because there is no analogy between such lands and federally owned lands which may not be taxed by a state.[101]

Time When State's Title to School Land Takes Effect. The date when a school land grant takes effect frequently assumes importance. The general rule is that the state's right to the land granted attaches as of the date of the grant if the land is already surveyed, and, if not, the land must be identified by an official survey. When the survey has been approved by the Land Department the grant becomes operative as to such land.[102]

---

[96] New Mexico reserves the minerals and mining rights in its sale of these lands and leases such rights on a royalty basis. Terry v. Midwest Refining Co. (C.C.A. 10th 1933) 64 F. (2d) 428, 430, 434. See also State v. District Court (1947) 51 N. M. 297, 183 P. (2d) 607.

[97] This interesting history and additional illuminating comments on the departure on the part of Congress from its previous traditional policy in this regard are set forth in detail in Murphy v. State (Ariz. 1947) 181 P. (2d) 336, 344-345, 351-353. The court scathingly criticizes "the ingenuity of politically ambitious men to obtain preferment" by improper use of the trust funds derived from the sale of such lands. *Id.* at 346.

[98] Downer v. Graham (C. C. A. 8th 1927) 21 F. (2d) 732, 733.

[99] Malmo v. Case (Wash. 1947) 184 P. (2d) 40, 42; State v. Northwest Magnesite Co. (Wash. 1947) 182 P. (2d) 643, 654.

[100] United States v. Swope (C. C. A. 8th 1926) 16 F. (2d) 215, 217, 219.

[101] Kelly v. Allen (C. C. A. 9th 1931) 49 F. (2d) 876, 878.

[102] United States v. Wyoming (1947) 331 U. S. 440; United States v. Morrison (1916) 240 U. S. 192, 210-212; United States v. Ickes (App. D. C. 1934) 72 F. (2d) 71, 75; Work v. Standard Oil Co. (App. D. C. 1927) 23 F. (2d) 750, 752, *rev'd on other grounds,* (1929) 278 U. S. 200, 208; State of Utah v. Work (App. D. C. 1925) 6 F. (2d) 675, 676. In this latter case the land had been included in a temporary petroleum withdrawal prior to the date of approval of the survey and, therefore, before the state's rights had vested. People v. Dorr, *supra* note 88.

A case illustrating this principle and involving a portion of a section 36 is *United States v. Wyoming.*[103] There were two main defenses to the suit. Wyoming claimed that the peculiar wording of its enabling act created an exception to the general rule that title to these school sections in place does not vest in the state until the sections have been surveyed, but the Supreme Court held otherwise, saying:

> Vesting in the State an immediate and irrevocable interest in the school sections before such sections had been identified by survey would be to complicate the performance of the Government's obligation with respect to the public lands.[104]

The state also contended that the section had been surveyed in 1892, prior to its mineral character becoming known, and that, therefore, the state's title had vested on the date the survey was approved. The Supreme Court, however, noted that the survey had only fixed the exterior boundaries of the township and marked one mile intervals on those boundaries without subdividing the township into sections, and that while section 36 lay in the southeast corner of the township and its southern and eastern boundaries were concurrent with the township boundaries, and while the section could have been identified by protraction of its two undetermined boundaries from the "one mile intervals" actually set on the township boundary, nevertheless, the northern and western section boundaries remained undetermined in fact, and therefore, "This was not a completed survey of Section 36." [105]

A leading case on this subject of school land sections, which finally decided a question which, very strangely, had remained undecided for many years,[106] is *West* [107] *v. Standard Oil Co.*[108] This case became famous because of the magnitude of the interests involved and because Congress intervened to compel its prosecution. School section 36 was situated in the productive oil field of Elk Hills, Kern County, California, which nearby development had proven to contain petroleum of many millions of dollars in value. The Standard Oil Company had succeeded to any title that the state might have had as a result of the federal grant in aid of public schools.[109] On January 26, 1903 the public survey of the section had been approved, and in 1910 the state issued patents for the land. The federal granting act had not provided for the issue of patents and the state had no evidence of title having been confirmed to it by the federal government, nor had there been any contest in the Land Department between the state and an adverse claimant whereby the character of the land had ever been determined. It had been returned as mineral land by the official surveyor [110] and later withdrawn from entry by Presidential Order and placed in a naval petroleum reserve. A contest was initiated by the federal government in the United States Land Office to determine whether at the date of approval of the official survey in 1903 the section was known to be mineral in character. Secretary of Interior Fall had originally dismissed this contest on legal grounds, without the question of known mineral character having been determined. This action provoked such criticism that Congress passed a special resolution [111] directing the Secretary to reopen the case and determine the issue of mineral character. Secretary Work, who had succeeded Fall, complied.[112] The oil company secured an injunction from the Supreme Court of the District of Columbia prohibiting the Land Department from proceeding with the contest, and this ruling was upheld by the court of appeals.[113] The Supreme Court of the United States [114] reversed these decisions and directed that the Land Department proceed with a determination of the mineral character, which was done, the Department's decision being that the land was known to be mineral at the date of approval of the survey in 1903 and hence that title remained in the United States.[115] The Supreme Court of the United States held that where there is involved an act granting public lands, but excluding those known to be mineral, the determination of the fact whether a particular tract is of mineral character ordinarily rests with the Secretary of the Interior. If the act provides for the issue of a patent, that instrument imports that a final determination of the nonmineral character of the land has been made and is conclusive of that point on collateral attack. The granting act may provide for other action by the Secretary equivalent to a patent, such as approval of a list of the lands,[116] which likewise imports that the necessary determination has been made.[117] Where the granting act makes no provision for issuance of patent or clear listing, as was the case here, the Secretary may have occasion to make a determination of the issue of known mineral character in a proceeding or contest where claims of right adverse to the state grant may be asserted. In such event any judgment evidencing title that may be issued as the result of such a contest imports the making of such determination. The Court held that Secretary Fall's dismissal of the contest proceedings on legal grounds, without making any determination of the mineral character of the land, was ''quasi-judicial'' and not a ''judgment'' [118] and, therefore, did not satisfy this last mentioned qualifying procedure.

---

[103] (1947) 331 U. S. 440. It will be noted that the leading cases on this subject of school lands are mainly suits involving valuable oil lands, brought by the United States on the theory that the school lands in question were known to be mineral at the effective date when title would otherwise have passed to the state, and hence have remained the property of the United States.

[104] *Id.* at 453.

[105] This case also discusses a very interesting point connected with the measure of damages for the wrongful extraction of mineral by the state's lessee, where the costs of extraction exceed the value of the mineral extracted and where the element of "good faith" is involved. A consideration of these features will be reserved for presentation later under the heading "Damages for Trespass."

[106] Over three quarters of a century, 1853-1929.

[107] West was at that time Secretary of the Interior, representing the United States.

[108] (1929) 278 U. S. 200, *reversing* Work v. Standard Oil Co. (App. D. C. 1927) 23 F. (2d) 750. See Colby, *The Law of Oil and Gas* (1942) 30 CALIF. L. REV. 245, 259-260.

[109] (1853) 10 STAT. 244.

[110] Another report had later classified it as non-mineral.

We may conclude from the foregoing that where the school land granting act does not provide for issuance of patent or other official evidence of passage of title from the United States, and where there has been no contest or other decisive determination by the Land Department as to the mineral character of the land, this question remains an open one to be later determined with respect to any particular piece of land embraced in a school section when that question arises.[119] The issuance of a state patent for such land is apparently treated by the court as having very little, if any, weight as far as the determination of the vital question of mineral character is concerned. This decision has had the effect of throwing doubt on the validity of state school section titles which had long been thought to be secure and to have been placed beyond any possibility of successful questioning.[120]

---

[111] (1924) 43 STAT. 15.

[112] State of California, Standard Oil Co. of Calif., Transferees (1925) 51 Land Dec. 141.

[113] Work v. Standard Oil Co., *supra* note 108.

[114] West v. Standard Oil Co. (1929) 278 U. S. 200.

[115] United States v. California (1935) 55 Land Dec. 121, *aff'd,* (1936) 55 Land Dec. 532. The foregoing opinions contain an exhaustive consideration of the law and facts and are valuable because of the light they throw on this general subject. An attempt was made to upset this decision of the Land Department and to secure a retrial of the issues by the court, but it proved futile. Standard Oil Co. of Calif. v. United States (C. C. A. 9th 1940) 107 F. (2d) 402, *cert. denied.* (1940) 309 U. S. 654, 673.

[116] Sometimes referred to as "clear listing."

[117] Copper Belt etc. Co. (1934) 54 Land Dec. 475, 476; James R. Crawford (1931) 53 Land Dec. 435, 437.

[118] West v. Standard Oil Co. (1929) 278 U. S. 200 at 211-214.

In another respect the *Standard Oil* case [121] has settled a legal problem which had long remained without final answer. As Judge Lindley has pointed out,[122] while there was no procedure prescribed in the act requiring an investigation by the federal land department and a determination of the mineral character of the state school sections, it had become the custom for the state land officials before patenting any of these state school lands [123] to obtain from the register of the local United States Land Office in whose district the land was situated a certificate showing that as far as the federal land office records were concerned there were no conflicting filings. As Judge Lindley states, "there is absolutely no authority for this so-called 'cerificate'." [124] It certainly could have no bearing on the basic and vital issue, the determination of the character of the land. When the issuance of these certificates was called to the attention of the Secretary of the Interior, he expressly repudiated any authority residing in the local officials to make them.[125] The Supreme Court of California had at first held that state patents issued on the basis of such certificates could be attacked collaterally by a mineral claimant,[126] but later reversed this ruling and held that these certificates issued by the United States Register had such potent legal effect that the state patents based thereon could not be attacked collaterally.[127] The fact that the *Standard Oil* case has so positively decided that the issuance of a state patent for school land does not, except in cases where there has been some preliminary determination that the land is not mineral, preclude an inquiry as to the mineral character of such land confirms Judge Lindley's opinion on this point, and the California Supreme Court has recently announced that these certificates issued by the registers of local land offices "were unauthorized and of no binding effect." [128] The Land Department expresses the same view as to the effect of the *West v. Standard Oil* decision and concludes:

---

[119] Scharf and Havenstrite (1941) 57 Land Dec. 348, 355-356.

[120] See also Ames v. Empire Star Mines Co., Ltd. (1941) 17 Cal. (2d) 213, 110 P. (2d) 13; People v. Dorr, *supra* note 88; Sliger Gold Mining Co. (1937) 56 Land Dec. 67, 72. The same principle applies to state patents issued under swampland grants to the states. United States v. O'Donnell (1938) 303 U. S. 501, 506, 508-509.

[121] *Supra* note 108.

[122] 1 Lindley, Mines § 144a.

[123] There is no provision in the federal granting act providing for the issuance of state patents for such school lands, and state legislation varies in the different states as to the requirements for the issuance of such patents. Unquestionably these state patents are not ordinarily open to collateral attack in those instances where the land is non-mineral and hence of the character contemplated as passing to the state by the grant. Where such lands were known to be mineral at the effective date of the grant, that question apparently remains open for determination.

[124] 1 Lindley, Mines § 144a.

[125] Instruction (1902) 31 Land Dec. 212.

[126] Hermocilla v. Hubbell (1891) 89 Cal. 5, 26 Pac. 611.

[127] Saunders v. La Purisima etc. Co. (1899) 125 Cal. 159, 57 Pac. 656. See also Worcester v. Kitts (1908) 8 Cal. App. 181, 96 Pac. 335.

[128] Ames v. Empire Star Mines Co., Ltd. (1941) 17 Cal. (2d) 213, 110 P. (2d) 13. See also People v. Dorr, *supra* note 88.

> While there exists the presumption that the land passed to the State under its original grant, this presumption is not conclusive but is open to contestation in the Land Department. There is in such cases no preliminary adjudication, actual or presumed by the Land Department as to the character of the land. There is no antecedent judgment, as there is in homestead and preemption cases, which is final and conclusive upon collateral attack. It follows, the question may be raised at any time by anyone in privity with the Government whether the lands are within the purview of the grants, and a mining locator is in such privity. See Lindley on Mines, Sec. 144; *West v. Standard Oil Co.*, 278 U. S. 200, 219.[129]

Presumably, attacks on state patents of long standing, even where issued without any predetermination as to the question of mineral character, will be met by defenses such as laches, lapse of time, etc., which under proper circumstances preclude any inquiry into the antecedent history of the grant.[130] Whether the federal statute of limitations[131] can be invoked seems still to be a moot question, at least as far as certification of lists of selected lands by the Land Department is concerned.[132]

Indemnity Grants in Lieu of Lands in School Sections. It was inevitable that some of the lands within the designated schools sections granted to the states would be found to conflict with prior legal claims. These might be Spanish, Mexican, or French grants, reservations for government purposes, or prior legal occupancy under other claims of right. In addition, as we have just noted, in those states where the school land grants were subsequent to the declared policy of Congress to reserve mineral lands for separate and special disposition mineral lands were either expressly or impliedly reserved. This latter policy has resulted in a large total acreage of proven mineral land being carved out of these school sections and lost to the states, particularly in the mining states of the West where there exist extensive mineral deposits. Congress, however, carrying out its consistent policy of liberality to the newly erected states, with particular emphasis on aid for educational purposes, has remedied this situation and compensated for these losses by providing, either in the original granting acts or by supplemental legislation, that the states might select elsewhere from the public domain equivalent areas of land as indemnification and in lieu of the base lands so lost.

Again, when Congress created the vast reservations in the public domain of the West, at first designated as "Forest Reserves," now known as "National Forests," there were included within these extensive withdrawals of public lands innumerable school sections. In order to preserve the integrity of these forest reservations and to permit the states to acquire other lands not surrounded by large tracts in such reservations which were withdrawn from other disposal or settlement, the states affected were also given the right to select other lands from the public domain in lieu of such included lands. This right of selection of an equivalent acreage elsewhere operated to give a state a right to waive its claim to such included school sections and to select other lands whether its title to the sections involved had become complete or not.[133]

Where the state had selected land in lieu of a school section included in a national forest at a time when neither base nor lieu lands were known to be mineral, and the state had done everything it was required to do to perfect its lieu selection, with a subsequent withdrawal of the land from private entry under the Act of 1910[134] having taken place, the selection will not be defeated even though it is still pending in the Land Department. The state has become the equitable owner of the land selected, and its rights are vested rights which all must respect. Any subsequent discovery of minerals will, therefore, not subject the land to the subsequent withdrawal order, for this would work "an inadmissible interference with vested rights."[135]

---

[129] Sliger Gold Mining Co. (1937) 56 Land Dec. 67, 72.

[130] 3 LINDLEY, MINES § 784. Also see United States v. Fullard-Leo (1947) 331 U. S. 256.

[131] (1891) 26 STAT. 1093, 43 U. S. C. § 1166 (1940).

[132] The Land Department says this question "has not been authoritatively settled." Copper Belt etc. Co. (1934) 54 Land Dec. 475, 479.

[133] Payne v. New Mexico (1921) 255 U. S. 367, 372-373; California v. Deseret Water etc. Co. (1917) 243 U. S. 415, 420.

A case involving a state school lieu selection, which at first glance might seem inconsistent with the ruling in *Work v. Louisiana* and *Cooper v. Roberts,* is *Charleston Mining Co. v. United States.*[136] A deposit of phosphate rock was involved, and the federal government established the fact that the land in question, which was claimed as indemnity for a portion of a school section 16 in the State of Florida,[137] was mineral land and that the selector was guilty of fraud in furnishing a false affidavit. It was contended, however, that since the grant of the original school section to Florida, and also the selection of indemnity lands, was authorized by act of Congress dated March 3, 1845,[138] it was immaterial whether the lands selected were mineral or not. The trial court,[139] though it "was much impressed by this contention," relying on *United States v. Sweet,* held that the Act of 1845, though "broad enough to cover mineral lands," was contrary to the policy of Congress as expressed in the legislation relating to mineral lands referred to in the *Sweet* case. The court makes no mention of *Cooper v. Roberts,* though it was commented on in the *Sweet* case and there differentiated on the ground that when the school grant to Michigan was made (1847), "the public policy respecting mineral lands had not been expressed in general and permanent laws, such as were afterwards enacted and carried into the Revised Statutes." Since the Florida school grant act antedated the similar Michigan act by two years, it would seem at first glance that the same rule would have applied. This is particularly true in view of the fact that the year following this decision by the trial court, in *Work v. Louisiana,* the Supreme Court of the United States again affirmed the rule announced in *Cooper v. Roberts.*[140] The Supreme Court in the Florida case did note the Louisiana decision, seemingly *contra,* but held that §§ 2275 and 2276 of the Revised Statutes, as amended by the Act of 1891,[141] superseded the indemnity land provision of the original Florida statute and required "that the indemnity lands to be conveyed thereunder shall not be mineral in character."[142]

---

[134] (1910) 36 STAT. 847, 43 U. S. C. § 141 (1940).

[135] Wyoming v. United States (1921) 255 U. S. 489, 501, 508-509. This decision was cited in Copper Belt etc. Co. (1934) 54 Land Dec. 475, 480; see also New Mexico v. Shelton (1932) 54 Land Dec. 112, 116.

[136] (1927) 273 U. S. 220, 224-227.

[137] The lands in question were a part of the public lands which the United States acquired by cession from Spain in 1821, and its mineral deposits are subject to the general mining laws of Congress. 1 LINDLEY, MINES § 28.

[138] (1845) 5 STAT. 788.

[139] United States v. Charleston Mining & Mfg. Co. (S. D. Fla. 1924) 298 Fed. 127, 129, *aff'd.,* (C. C. A. 5th 1925) 3 F. (2d) 1019.

[140] The state grants to Louisiana were dated 1849 and 1850.

[141] (1891) 26 STAT. 796, 43 U. S. C. § 851 (1940).

[142] Charleston Min. Co. v. United States (1927) 273 U. S. 220, 227. Had the land in question been in one of the base school sections instead of a lieu selection the case would be governed by the Cooper v. Roberts and Work v. Louisiana decisions.

In the selection of lieu or indemnity school lands it is essential procedure to submit the selection and the accompanying documents to the federal Land Department for approval, since the proceeding involves the granting of title to other federally owned public lands. In other words, all lieu lands must be selected ''under the direction and subject to the approval of the Secretary of the Interior.''[143] However, the officers of the Land Department do not have arbitrary authority to accept or reject a filing. They must give effect to the conditions existing when the selection was made, and if it was valid then they are not at liberty to disapprove or cancel it by reason of a subsequent change in the status of the base tract. These provisions under which selections are made are ones inviting and proposing an exchange of lands. Congress has said, in substance, to the states that they may select and take in lieu of base lands that are found to be mineral, to which other valid claims have already attached, or to which the states surrender title because the base land is in a federal reservation, a like area from the unappropriated nonmineral lands elsewhere on the public domain. Acceptance of such proposals and compliance with their terms confer vested rights in the selected lands which the land officers cannot lawfully disregard. While the duty is cast upon the Secretary of ascertaining whether the selector is acting within the law in respect of both the base land and the land selected, and of approving or rejecting the selection accordingly, the power conferred is ''judicial in its nature,'' and the lawfulness of the selections must be determined ''as of the time when the exertion of the authority was invoked by the lawful filing of the list of selections.''[144]

Act of 1927—Granting Mineral Lands in School Sections to States. A radical change in the law governing the disposition of state school section lands was inaugurated with the passage of the Act of January 25, 1927.[145] The long standing policy of reserving known mineral lands from the school land grants and disposing of such reserved lands under the federal mining laws was terminated.

To summarize briefly, the previous policy had been to reserve from the operation of these school land grants all lands which were known to be mineral in character at the date they were officially identified by approval of the public survey of each school section or at the date of the grant, provided the section had already been officially surveyed. These school land grants, however, seldom made any provision for the issuance of patents, either federal or state, or any equivalent procedure to evidence the transfer of title of such school sections to private individuals. Until some definite determination had been made as to its known mineral character at the critical date, it was uncertain whether or not a grantee from the state had actually become vested with a title which was free from attack. This determination was a function exercised by the federal Land Department, representing the federal government in the disposition of its public lands. That Department early took the position that in the case of these school land grants the presumption existed that the land was of the character contemplated by the grants, and where identified by survey that title had passed to the state.[146] Until some occasion arose for the determination of the known mineral character of the land at the critical date, the possibility always remained that the title claimed by the state or its grantees might be unsettled by a proceeding in the Land Department to test this question. This state of uncertainty, which had on many occasions been called to the attention of Congress, resulted in the passage of the Act of 1927.[147]

---

[143] Payne v. New Mexico (1921) 255 U. S. 367, 369.

[144] *Id.* at 370-373. See also Wyoming v. United States (1921) 255 U. S. 489, 500.

[145] (1927) 44 STAT. 1026, 43 U. S. C. § 870 (1940). See also Instructions (1927) 52 Land Dec. 51; (1928) 52 Land Dec. 273.

The main purpose of the Act was to vest in the states title to those school section lands which were of known mineral character at the critical dates and which, were it not for the Act, would have been reserved from the operation of the prior school land grants.[148] It did not, however, validate or confirm prior unauthorized sales of known mineral lands, and it is still necessary to have a determination of whether or not the land was known mineral land at the time the state's rights under the original grant attached.[149] Of course, the Act does not affect the title to school section lands which were not known to be mineral in character on those effective dates even if minerals were subsequently discovered in them, nor does it affect the title to the mineral lands intended to be granted to the states by its terms where other valid claims of title under other laws had already become vested. The Land Department clearly retains jurisdiction to determine these last mentioned claims.[150]

This additional grant is made, however, upon the express condition that each state shall reserve ''all the coal and other minerals in the lands so sold . . . together with the right to prospect for, mine and remove the same.'' The states are empowered to lease these mineral deposits ''as the state legislature may direct,'' the proceeds to be devoted to the support of the public schools, and any violation of this mineral leasing policy will result in a forfeiture of such lands and minerals to the United States. Lands already reserved by the United States and all lands in Alaska are excluded from the operation of the act. Existing rights arising under other grants were recognized and the Act by its terms was not to apply to indemnity or lieu selections.

Amendment of May 2, 1932.[151] This amendment clarified the original act by stating that its provisions were not to apply to lands ''heretofore disposed of'' by the states. It also permitted the states to relinquish title to lieu lands selected after the date of the act and thereby to become entitled to the base land, and provided further that in the event of the restoration of lands previously reserved the provisions of the Act of 1927 granting such mineral school section lands to the states shall become effective.[152]

---

[146] Scharf and Havenstrite (1941) 57 Land Dec. 358, 356-357. This contains an exhaustive consideration of the history of these grants, the law governing their administration, and the Act of 1927.

[147] At the time of the enactment of this statute there were pending before the land department more than 1,700 proceedings based on alleged known mineral character of school section lands there brought into question. This situation had proved to be quite an embarrassment to state school funds. Scharf and Havenstrite, *supra* note 146 at 358.

[148] "The purpose and terms of the act, as well as its legislative history, seem clearly to indicate that the intention of Congress was to vest in the states, finally and irrevocably, the full title to school sections in place wherever the only bar to the operation of the previous school land grants was the then known mineral values of the lands, provided they had not become subject to rights, reservations or court proceedings or disposed of as indemnity or lieu lands." *Id.* at 358-359.

[149] Instructions (1930) 53 Land Dec. 30, 34-35.

[150] Scharf and Havenstrite, *supra* note 146 at 360-361.

[151] (1932) 47 Stat. 140, 43 U. S. C. § 870 (1940).

52 Land Dec. 679.

[152] Instructions (1932) 53 Land Dec. 664, 665-666; State of New Mexico (1929)

Act of June 21, 1934.[153] The Act of 1927 as amended in 1932 did not, however, entirely remedy the situation, and Congress was made aware of the fact that "to clear the atmosphere" more completely there should be provided some sort of evidence of a satisfactory title, which would set that matter at rest for all time. Therefore, the Act of 1934 was passed, authorizing the Secretary of the Interior, upon application by a state, to "cause patents to be issued to the numbered school sections in place" which had been "granted for the support of common schools" by any Act of Congress, including the Act of 1927, "to which title has vested or may hereafter vest in the grantee States, and which have not been reconveyed to the United States or exchanged with the United States for other lands." The date when title vested in the state and all limitations on the title were to be shown in the patents. It was expressly provided that "In all inquiries as to the character of the land for which patent is sought the fact shall be determined as of the date when the State's title attached."[154] Thus a conclusive determination of the facts essential to the vesting of title in the state, including that of mineral character at the critical time, and the issuance of a patent which may not be collaterally attacked to evidence such decision and divest the Land Department of further jurisdiction over the land, is now expressly authorized.[155]

The Act of 1927 has resulted in state leasing systems for all minerals in school section lands that these states had not already disposed of. The states concerned have quite uniformly enacted laws providing for the leasing of mineral lands in conformity with the provisions of this federal act.[156]

This act, while salutary in purpose, has added some confusion to an already complicated legal situation. We have commented on some of the perplexing questions involving the mineral character of school lands when ownership of reserved minerals could only be acquired under the federal mining laws. It was then vital to determine the effective date of the school grant, since all known mineral lands as of such date were reserved to the United States to be disposed of under its mining laws. Now it becomes equally vital to determine whether any private rights under the federal mining laws have lawfully attached to such known mineral lands prior to January 25, 1927, because the federal act of that date expressly saves "all the rights of adverse parties recognized by existing law . . . ." We have, as a consequence, two important dates which must now be taken into consideration when claimants assert title under the federal mining laws to any portion of these school sections. A mineral claimant in order to prevail as to any portion of a school section must now prove that his mining claim was initiated prior to January 25, 1927 [157] and also that the land so claimed was known to be mineral in character on and prior to the date the state's title would otherwise have become effective under its school land grant.[158]

---

[153] (1934) 48 STAT. 1185, 43 U. S. C. § 871a (1940).

[154] Scharf and Havenstrite, *supra* note 146 at 362-363.

[155] *Id.* at 364.

[156] California had anticipated this federal act, in so far as the leasing of its mineral lands are concerned. Prior to the passage of the federal act, California and its grantees owned all of the minerals in state school lands that were discovered and became known subsequent to the effective date when title to the school sections would normally pass to the state. In Cal. Stats. 1921, p. 404, California inaugurated a policy of reserving and leasing its mineral lands. This state act contained elaborate provisions governing the making of such leases. This act has been amended and added to from time to time, and when the federal act here under consideration was passed in 1927 California had already in substance complied with the federal act. California's mineral reservation and leasing provisions are now codified in CAL. PUB. RESOURCES CODE §§ 6401-6402, 6501-7055. This state leasing act is administered by a State Lands Commission of the Division of State Lands in the Department of Finance.

---

[157] Mangan and Simpson v. Arizona (1928) 52 Land Dec. 266, 268.

[158] Instructions (1930) 53 Land Dec. 30, 33-34; Scharf and Havenstrite, *supra* note 146 at 364.

IONE-CARBONDALE CLAYS, AMADOR COUNTY, CALIFORNIA*

By F. T. Johnson ** and Spangler Ricker **

OUTLINE OF REPORT

	Page
Summary	491
Introduction	491
Acknowledgments	493
History	493
Physical features	493
Ownership	495
Description of deposits	495
Exploration by Bureau of Mines	497
Method of sampling	498

Illustrations

Fig. 1.	Map showing portion of Ione-Carbondale clay deposits and drill holes, Amador County	492
Fig. 2.	Cross sections of portion of Ione clay deposits, Amador County	494
Fig. 3.	Cross sections of portion of Ione clay deposits, Amador County	496

SUMMARY

The Ione-Carbondale clays area is 2 miles northwest of Ione, Amador County, California. It was explored during the war by the Bureau of Mines to obtain data on the alumina content and to recover representative samples for beneficiation tests for alumina recovery.

Seventy holes aggregating 8,837 feet were drilled, and about 10.3 acres of land was cleared of underbrush. Maps and cross sections were compiled showing location of holes, analyses, and other pertinent data.

The clay beds vary in thickness from 13 to 196 feet, and are covered by a loose overburden, averaging about 11.9 feet in thickness. The ratio of overburden to clay is 1:8.2. Analysis of a composite sample showed the recoverable alumina (Al_2O_3) and Fe_2O_3 content to be 23.6 percent and 2.8 percent, respectively.

Topography of the clay area is ideal for open-pit mining methods and plant site.

INTRODUCTION

Investigation of alumina-rich clays for the possible production of aluminum was made during the recent war period, when the shortage of bauxite was becoming critical.

Results of field examinations by the Bureau of Mines and the federal Geological Survey indicated that one of the most promising areas for the development of alumina-rich clays is in the Ione-Carbondale district.

The preliminary investigation of the Ione-Carbondale clay deposits was made in August 1942 by engineers[1] of the Bureau in company with Victor T. Allen and M. N. Bramlette of the federal Geological Survey. Wherever exposures permitted, samples of the clays were collected and sent to the Salt Lake City laboratory for determination of the available alumina content. Analyses of the samples were encouraging, and exploration by the Bureau began in November 1942.

---

* Reprinted from U. S. Bureau of Mines Report of Investigations 4213, March 1948.

** Mining engineers, Reno Branch, Mining Division, Bureau of Mines, Reno, Nevada.

[1] Fremont T. Johnson and Joseph S. Hollister.

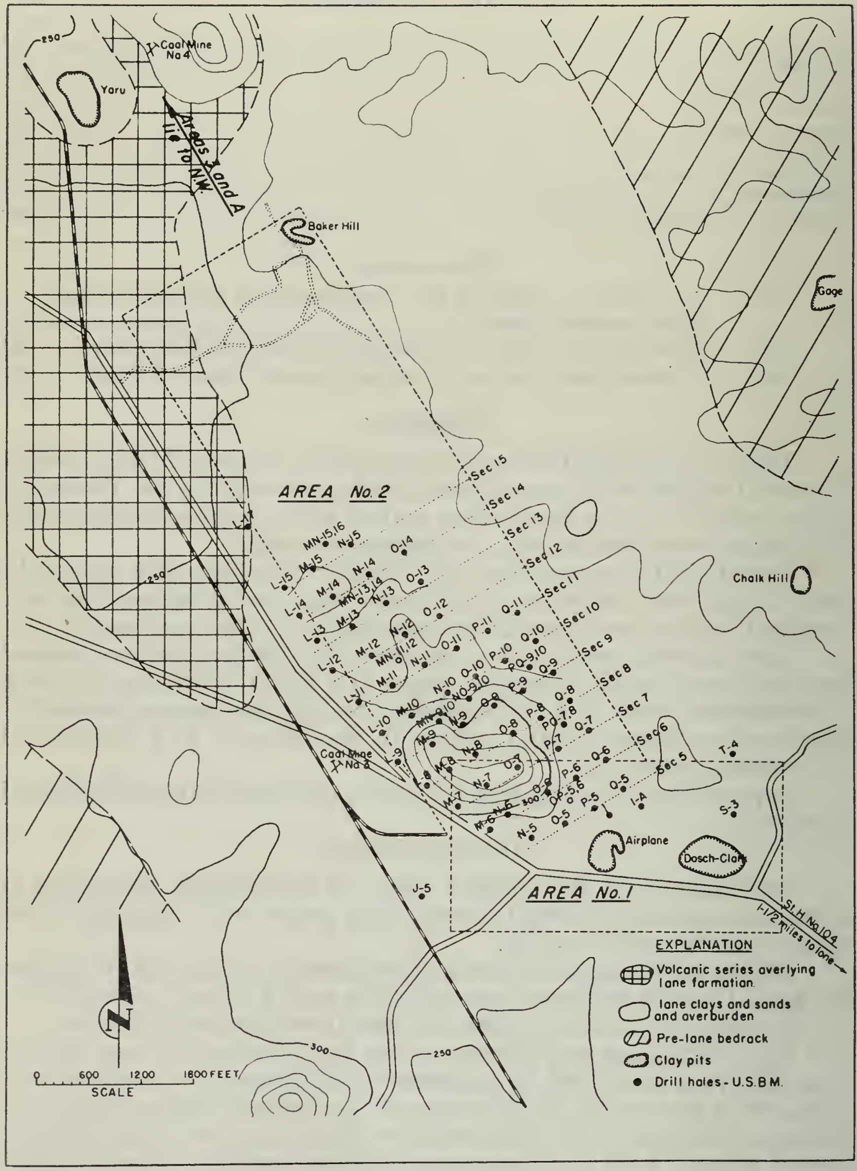


FIGURE 1. Map showing portion of Ione-Carbondale clay deposits and drill holes, Amador County.

ACKNOWLEDGMENTS

In its program of exploration of mineral deposits, the Bureau of Mines has as its primary objective the more effective utilization of our mineral resources to the end that they make the greatest possible contribution to national security and economy. It is the policy of the Bureau to publish the facts developed by each exploratory project as soon as practicable after its conclusion. The Mining Division, under the direction of Lowell B. Moon, chief, conducts preliminary examinations, does the actual exploratory work, and prepares the final report. The Metallurgical Division under the direction of O. C. Ralston, chief, analyzes samples and makes beneficiation tests.

The Ione-Carbondale project was a part of a program in the Western Region directed by Spangler Ricker, of the California field office, which is under the general supervision of A. C. Johnson, Chief, Reno Branch, Mining Division. The field work was supervised by F. T. Johnson.

Special acknowledgment is made to Victor T. Allen and Ralph King of the federal Geological Survey for their cooperation throughout the program. Analytical work was done under the direction of A. C. Rice of the Reno Rare and Precious Metals Experiment Station.

HISTORY

Clays for fire brick and other ceramic uses have been mined from the Ione-Carbondale pits for many years. Accurate statistics as to the total tonnage that has been mined are not available, but various estimates put it at less than a million tons. Chemical analyses by the ceramic industries have long indicated that the clays have a high, though variable, alumina content.

Variation of the physical properties of the clays caused abandonment of certain pits, and search was made for other locations where more suitable clays might be mined. Many hand-auger holes, as well as other test holes, were put down from time to time in the search for better grades of clay. The records made are not available at present. However, by making evaluations from the samples collected and analyzed by the Bureau, considerable areas were found to contain enough high-alumina clay to justify further exploration in the district.

At present, only a few of the pits are operating. About six carloads of clay a day are being sent to various ceramic plants in California.

About 15 to 20 years ago, extensive drilling was carried on to determine the extent and thickness of the lignite underlying the Ione clay. No accurate records were made of the clays, although drilling disclosed the fact that thick beds are present. Many wells in the district also are reported to have encountered clay beds.

PHYSICAL FEATURES

In general, the area under consideration is quite flat. A few rolling hills 50 to 100 feet above the general level of the valley lie in the southern part of the district. Most of the valleys underlain by the clays are about 250 feet above sea level. A large part of the country is covered by brush, scrub oak, and live oaks. Some of it is open, however, and is used for grazing. No farming is being carried on in the district at present.

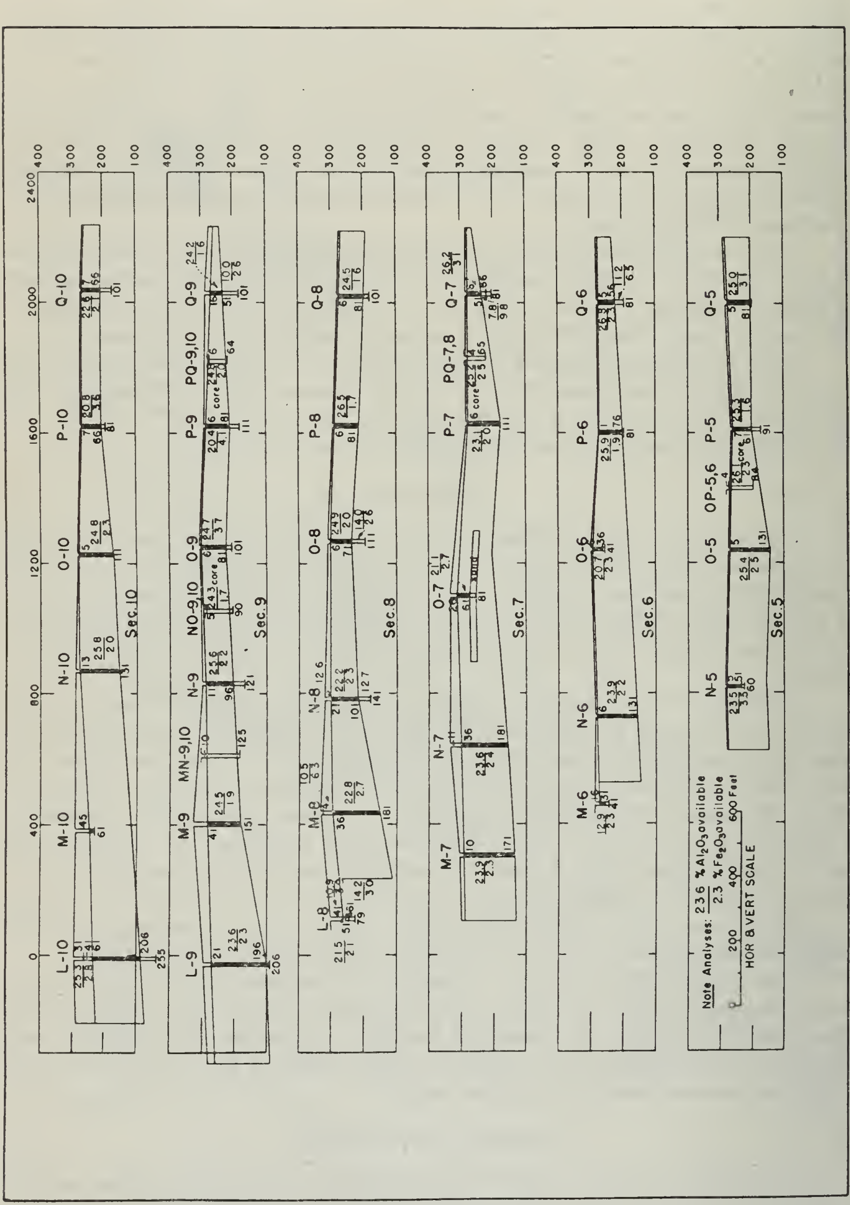


FIGURE 2. Cross sections of portion of Ione clay deposits, Amador County.

A branch of the Southern Pacific Railroad parallels the clay deposits and now is used to transport the clay to various ceramic plants. Good paved roads also traverse the area, rendering it accessible to any sort of transportation. The clay deposits are about 2 miles from Ione, 12 miles from Jackson (the Amador County seat), 48 miles from Stockton, and 46 miles from Sacramento. It is about 92 miles south by railroad to Riverbank, where an aluminum-reduction plant is located.

Ordinary commodities can be obtained in Ione or Jackson, whereas goods of any kind can be purchased in Stockton or Sacramento, less than 50 miles distant.

Average rainfall and temperatures are not extreme; from November through March, however, rains may seriously interfere with mining operations. The climatology of Ione is shown in the following tabulation:

Month	Period 1878-1915 average rainfall (inches)	Period 1878-1915 average temperature (° F.)
January	3.98	46.1
February	3.21	49.1
March	3.68	52.9
April	1.91	58.2
May	1.14	64.9
June	0.25	73.0
July	.00	78.1
August	Trace	77.3
September	0.38	70.2
October	1.11	61.1
November	2.08	52.3
December	3.24	47.3
Annual	20.98	60.9

OWNERSHIP

Areas I and II and a possible plant site are in what is known as the Arroyo Seco grant, which has been acquired recently by Charles Howard, 1601 Van Ness Avenue, San Francisco. G. A. Sterkweather, Kohl Building, San Francisco, has a lease on the clays and sands mined within the limits of the grant.

Most of area III and the northern part of area A are owned by the Yosemite Portland Cement Company of Merced. The northern part of the western margin of area III is owned by Smith V. Parker, whereas the southern part of the same margin is owned by Mrs. Emma Stomas of Amador City, California. The southern two-thirds of area A is owned by the Pacific Portland Cement Co., 417 Montgomery Street, San Francisco.

DESCRIPTION OF DEPOSITS

The Ione clays are the product of Eocene tropical weathering on what was probably a relatively flat terrain. The weathered products were transported by sluggish streams and deposited in a lagoon protected from the Eocene sea. The bottom of the lagoon probably was irregular, which locally permitted the clays to settle in pockets and gradually fill the entire basin. At times considerable plant material was transported; today these are lenticular lignite deposits. In general, these are more common near the base of the clays. Owing to the peculiar type of derivation and deposition, variations in composition of the clays are to be expected. The average alumina content is the important consideration.

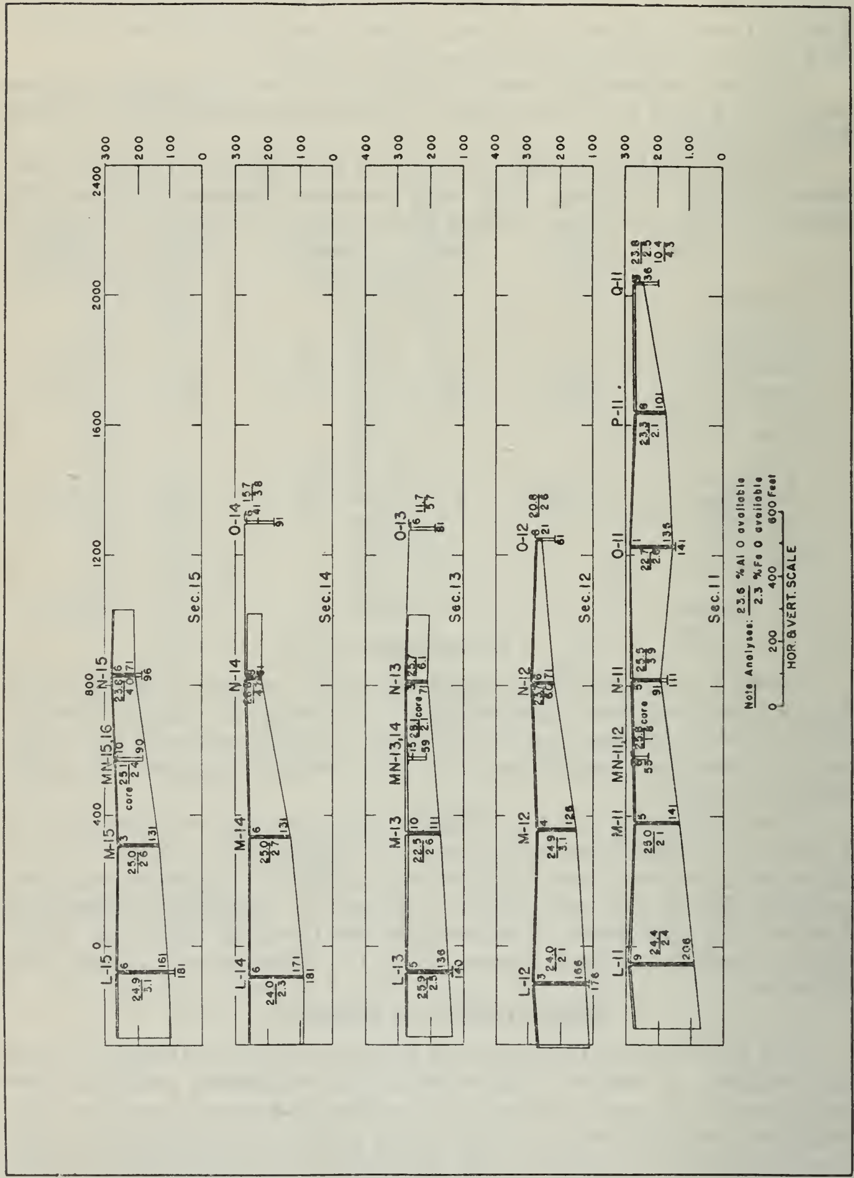


FIGURE 3. Cross sections of portion of Ione clay deposits, Amador County.

Some of the old streams deposited sand instead of clay. These areas, however, can be avoided easily in any mining operation. Where the sands are underlain by clay, it may be profitable to strip them in conjunction with mining.

Limits and extent of the deposit have not been determined fully. Drilling was done where the greatest tonnage of clay could be blocked out in the shortest possible time. Drilling records show the east side of the area explored to be thinner and to contain more sand. This indicates the eastern limit of the area drilled or a sand bar that was formed by one of the many streams emptying into the basin. The latter seems more probable, as 30 feet of clay is exposed at Chalk Hill to the east of the explored tract. Such sand bars will be found throughout the clay deposit. To avoid them, drilling should precede mining. The ratio of overburden to clay has been determined to be 1:8.2, and the average depth of overburden is estimated as 11.9 feet. The clay beds range in thickness from 13 to 196 feet.

EXPLORATION BY BUREAU OF MINES

Preliminary channel samples were taken from numerous opened clay pits in the area. These indicated 19.7 to 31.1 percent available Al_2O_3 and less than 2 percent available Fe_2O_3. The average available alumina for 18 samples was 26 percent.

The most favorable areas shown by preliminary sampling were explored by drilling on 400-foot centers. Sixty-two holes aggregating 7,578 feet were chip-drilled. In addition, 1,259 feet of core drilling was done in 16 holes to check chip-drilling results and more completely to determine the nature of the clay within the 400-foot blocks. Holes were spaced principally at 400-foot intervals and as a rule were stopped when low-grade clay or sand was encountered. Several holes were abandoned owing to loss of water. Figure 1 shows plan of areas I and II and location of drill holes. Figures 2 and 3 show cross sections of clay beds and analyses.

Nine prospect holes were drilled at widely separated locations in the Carbondale district to formulate plans for future drilling. One hole disclosed 85 feet of clay averaging 24.2 percent Al_2O_3 and 4.4 percent Fe_2O_3, with 6 feet of overburden. This hole was 1,600 feet from the Yosemite Portland Cement Company pit, where 7 feet of clay carrying 23.3 percent available Al_2O_3 and 1.1 percent Fe_2O_3 is exposed. Nearly all of the good clays were covered by a mantle of sand, gravel, or sandy clay ranging from 30 to 100 feet.

The moisture content of the clay was determined to be 16.2 percent. This average was based upon a total of 10 samples that were carefully taken, sealed, and sent to the Salt Lake City experiment station for moisture tests. For volume, 20 cubic feet was used per ton of clay in place.

A typical core analysis was as follows:

Ignition loss + H_2O	12.93
Silica (SiO_2)	53.56
Aluminum (Al_2O_3)	26.96
Iron (Fe_2O_3)	3.34
Titanium and zirconium ($TiO_2 + ZrO_2$)	1.68
Calcium (CaO)	0.58
Magnesium (MgO)	0.37
Sodium (Na_2O)	0.23
Potassium (K_2O)	0.47
Total	100.12

METHOD OF SAMPLING

A special study was made by Bureau engineers and the Western Geophysical Drilling Company of Los Angeles on October 7, 1942, to determine the most efficient method of sampling the Ione-Carbondale clays. Experiments proved that, by using an ordinary drag bit with water under pressure, chips large enough for sampling could be collected. Drilling and sampling by this method were checked against the results of core drilling and showed that, although exact checks were not obtained, the variations were neither consistently high nor low. Chip sampling progressed three times as fast as core drilling; therefore, this method was adopted.

Chips ranging from ¼ to 1 inch in diameter and up to ⅛ inch in thickness were obtained and collected on a screen tray and washed by dipping the tray into water. Samples were taken for each 5-foot interval, and after the chip samples were dried and crushed, composites for analysis were made up of longer samples. Average content on a dry basis of available Al_2O_3 and Fe_2O_3 was 23.6 percent and 2.8 percent, respectively.

Assays of chip, core, channel, and sludge samples show a reasonable conformity. Following is a comparative table showing results of chip and core methods, with analyses on a dry basis, in percentage, of available Al_2O_3 and Fe_2O_3.

Hole L-10—Core				*Hole L-10—Chip*	
Percent		*Core recovery, feet*	*Interval, feet*	*Percent*	
Fe_2O_3	Al_2O_3			Fe_2O_3	Al_2O_3
6.0	12.0	4.3	11-16	3.4	10.7
2.7	12.7	6.3	16-31	3.2	14.7
3.5	22.5	8.6	31-41	2.8	25.3
3.0	21.0	3.5	41-46	2.2	15.2
2.3	11.3	4.6	46-51	2.8	11.0
1.8	18.8	4.0	61-71	1.9	14.2
1.6	22.4	8.7	71-81	1.7	22.0
2.0	22.6	9.5	81-91	3.2	22.9
2.6	25.4	7.0	91-101	3.3	25.4
1.9	29.3	9.9	101-111	2.5	27.0
1.5	28.5	8.2	111-121	1.6	25.0
1.3	26.8	22.7	121-146	1.6	26.6
2.8	23.1	5.0	146-151	1.6	26.5
2.8	23.7	17.3	151-171	2.1	25.7
3.1	21.7	15.0	171-185	3.6	25.2
Hole P-5—Core				*Hole P-5—Chip*	
1.4	26.0	---	19-31	1.5	25.9
1.0	26.4	---	31-41	1.4	25.0
2.5	21.7	---	41-51	1.6	25.5
2.0	21.6	---	51-61	2.4	22.6
Hole Q-6—Core				*Hole Q-6—Chip*	
1.2	25.8	2.9	5-16	1.4	30.3
1.4	27.7	10.2	16-31	1.3	26.4
1.9	25.7	2.9	31-36	2.2	23.8
4.9	23.7	6.7	36-46	4.7	23.3
7.2	21.3	4.9	46-56	6.0	22.9
15.5	11.8	6.6	56-66	8.3	8.4
4.4	18.3	5.0	66-71	6.4	10.1
5.9	12.0	10.0	71-81	4.8	14.5

Sludge samples were taken at regular intervals in hole P-5 while drilling by the chip method. The weighted average analysis was 21.4 percent and 2.7 percent available Al_2O_3 and Fe_2O_3, respectively.

ADDRESS OF GOVERNOR EARL WARREN TO THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, INC.

SAN FRANCISCO, CALIFORNIA, FEBRUARY 14, 1949

Ladies and Gentlemen:

I welcome this 1949 migration of miners to California and to the City of San Francisco which is so indebted to the miners of 1849 for its very foundations, as well as for its development into a great world city.

All cities, of course, are built by gold, but this one was built by gold direct from the mines of this Western country, much of it without first going to the mint, but simply by being weighed over the counters of the banking houses and trading establishments.

I welcome you to Nob Hill, upon which this hotel is located, because it was first built upon by those pioneer Californians who made their initial fortunes either directly or indirectly through the gold and silver of our Western mines. The very foundation of this Fairmont Hotel was laid by Bonanza Jim Fair for a mansion that would outdo all the others, and the hotel itself was built by his daughter as a memorial to him with the millions he took from the Comstock Lode. Here in San Francisco, streets and parks and buildings perpetuate the names of those who came to mine and developed a state that has never lost its youthful enthusiasm or its power of attraction to people in every part of the world. We still conjure with the names of Sutter and Marshall and Brannan and Flood and Mackay and Sharon and Ralston. The Palace Hotel where you will hold your banquet tomorrow night is also a product of the mines. So many millions were spent on it that it became known as Ralston's ''folly''. The Gold Rush of '49 was an amazing era of adventure, courage and ingenuity, but colorful and spectacular and dynamic as it was, it could not compare in numbers with the migration to California since 1940.

It might interest you to know that in 1849 at this time of the year there were few, if any, more people in the entire City of San Francisco than there are in this gathering today; certainly not nearly as many as there are registered for your convention. California was little known by the world before that time, although weird fables of the gold, which was then undiscovered, had attracted the Spanish, Portuguese, English, French and Russian navigators for two centuries to explore our coasts in hope of finding great treasure here. But they all left except the Spaniards who built a little chain of missions, 21 in number, spaced between San Diego and San Francisco Bay according to the distance a man could travel in a day on horseback. And, when gold was discovered in the foothills of the Sierra Nevadas about a hundred miles from here on January 24th, 1848, there were fewer than 15,000 people—exclusive of native Indians—in all of what is now California. In San Francisco there were only a few hundred people living in adobes, log cabins and tents. The only buildings that remain today from that era are Dolores Mission and the little old Presidio, now used as an officer's club on the military reservation.

But at precisely this time of year in 1849, there were dozens of ships on their way from all parts of the world and hundreds were being outfitted for the trip. Before the year 1849 ended there were eight hundred ships in the Bay and San Francisco was a city of 50,000 people.

The little band of people living here in the pre-gold days were a kindly, hospitable people who always had the latch string out for strangers. There was always a meal, lodging, a night of music and dancing, and a fresh horse available the following day to take a traveler to his next stop. They were a carefree people and San Franciscans have never entirely abandoned that way of life. I speak of that at the outset of your convention, because it is easy here for visitors of most serious purpose to acquire that same spirit regardless of the important work they have to do.

Being a lawyer by profession, I come armed with evidence of the fact. It seems that the American Institute of Mining Engineers met in San Francisco, its first, last, and only time before this, just fifty years ago, in the gay nineties. Why they remained away so long, thereafter, most people, I am sure, do not know. Perhaps some of you do not know. But I found out. In preparing for this welcome I thought that I might gain some inspiration from the reports of that early day convention. And this is what I ended up with—an editorial from the Engineering and Mining Journal, dated October 7, 1899, volume 68, no. 15, p. 421.

''AMERICAN INSTITUTE OF MINING ENGINEERS MEETING''

''The members of the American Institute of Mining Engineers who attended the San Francisco meeting, met with an enthusiastic welcome and received a great deal of attention, as was to be expected, in the chief city of a State so largely interested in mining as California. The time of the members, was in fact, so much taken up that very little was left for the actual business of the meeting. This was compressed into three brief sessions. Nearly all the papers submitted were read by title only, and of the few that were read, either completely or in abstract, only one was discussed at all, and that in a very brief and inconsequent way. There was no time for discussion, which was once supposed to be the chief object of these meetings. If more such meeting are held, it will soon be necessary to choose between business and outside attractions; and if the business is to be carried on entirely by written and printed discussions, it might be well to dispense with the meetings altogether and the expense to the Institute and individuals which they involve.''

But we are not living in the Gay Nineties now. San Francisco has grown up considerably in the meantime and besides, the mining industry doesn't have so much to celebrate at the present time. In those halcyon days mining itself was a carefree business.

The public domain was wide open for mineral development.

Both prospecting and location were encouraged.

We were on the gold standard.

Minerals could be sold for what they were worth, both at home and abroad.

The industry was cushioned by the protective tariff.

The profits that were made could be kept as a reward for daring and industry.

And executive closing orders had not yet been conceived.

It was hardly necessary in those days to have eight divisions, ten committees and sixty-six sessions, as your 1949 program announces.

We are tremendously interested in your convention. We have a great stake in the mining industry in California. More minerals have been discovered here than in any other state of the Union, perhaps more than any other place of comparable size in the world. We produce more than 60 mineral products commercially, and we are among the four leading states of the Union in the production of more than half of them. The total value of our mineral production in California last year is estimated at one billion, one hundred million dollars. This is an increase of 245 million dollars over the 1947 total of 854 millions, and is our largest annual mineral value on record.

We wish these figures actually represented what they imply. If they did, it would mean that our mining industry is flourishing, but they do not. Our increase over former years is due very largely to a slight increase in petroleum and natural gas production and to an increase in the price of petroleum. As a matter of fact, all metals registered a decrease in the quantity of ore mined during the year.

In the aggregate that does not spell the progress we wish for our mining industry. We want our great petroleum industry to be encouraged to do the exploration work that will bring in new wells to compensate for the withdrawal of known reserves. We want our deep lode gold mines to be encouraged to resume operations and exploration work of all kinds revived throughout the state. We want our infant steel industry to be encouraged. We want to see government stock piling of critical materials for national defense. The drain of world war II on the richest ore bodies of our nation has necessitated not only the exploration of marginal deposits and the development of new techniques for their extraction, but also the continuous operation of such mines by a work force that will have the ''know-how'' in times of emergency to respond with dispatch. We who live out here on the Pacific Coast and who were closer to the infamy of Pearl Harbor than were other parts of the country, cannot escape the thought that if there should be a next time we will either be prepared or it will be too late. And we cannot be prepared without critical minerals being stored in the vicinity of the places where they will be needed.

We need a thriving mining industry here to support the other industry which we must have in order to supply jobs for the millions who have recently come to us. It is difficult for people to understand how we have grown in California and the need we have for basic industry to stabilize our economy. In 1920 we had 3½ million people. By 1930 we had grown to 5½ million. In 1940 we had almost 7 million. And now the United States Census Bureau tells us that we have 10 million, one hundred thousand people, a gain of 3 million, two hundred thousand in 8 years. If we are to sustain these people we must have an orderly development and conservation of all our natural resources;—water, soil, hydro-electric power, minerals, timber. We have been blessed with an abundance of these things. Properly developed, they will support an agricultural and industrial economy that will provide jobs, not only for the ten million people we have now, but also for the ten million who are coming in the next few decades. The other Western states have similar problems and potentialities. We want to see them develop in the same manner. We believe it will add strength and wealth to the nation.

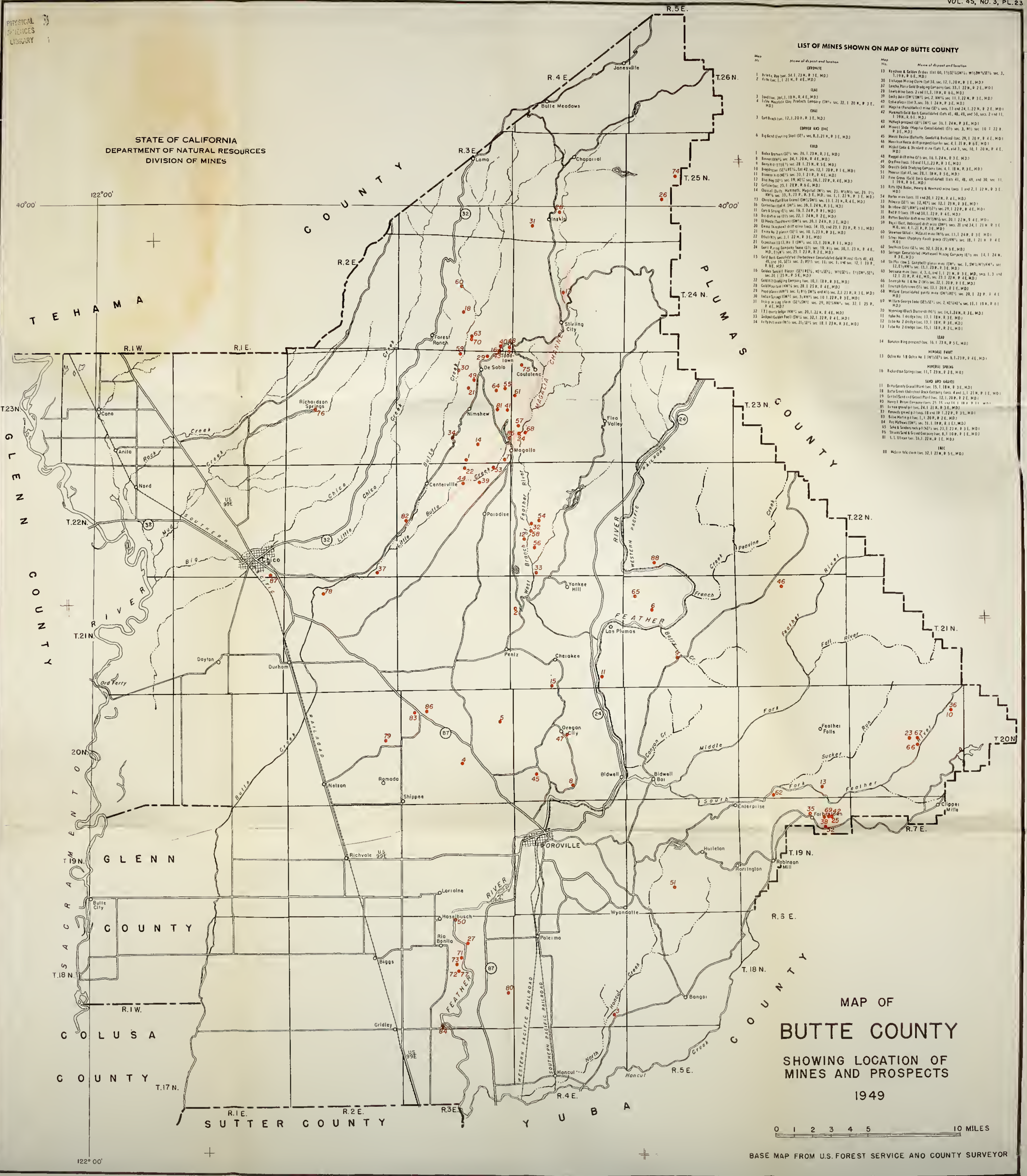
We know that you, too, are interested in our Western country. We believe that you can still do for us in 1949, in your very much broadened field of activity, what the mining industry did for our state a hundred years ago. You can help us to build the foundation for the greater destiny which we believe is in the making for this Western country.

Out here on the rim of the Pacific Basin we believe the billion people who live on its shores are destined to be our friends and neighbors. We believe that through our great ports we will exchange with them goods and friendly visits that will make this a more dynamic nation, and the world a more understanding place in which to live. We recognize the importance of your industry in such a program and we welcome you to California.

o

99478-B 11-48 2M

PHYSICAL SCIENCES LIBRARY



STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES

MAP OF
BUTTE COUNTY
SHOWING LOCATION OF MINES AND PROSPECTS
1949

0 1 2 3 4 5 10 MILES

BASE MAP FROM U.S. FOREST SERVICE AND COUNTY SURVEYOR

LIST OF MINES SHOWN ON MAP OF BUTTE COUNTY

Map No.	Name of deposit and location
	CHROMITE
1	[illegible] (sec. 34, T. 23 N., R. 3 E., M.D.)
2	Fritz (sec. 1, T. 21 N., R. 4 E., M.D.)
	CLAY
3	Bond (sec. 36, T. 18 N., R. 4 E., M.D.)
4	Table Mountain Clay Products Company (SW¼ sec. 22, T. 20 N., R. 3 E., M.D.)
	COAL
5	Carl Brock (sec. 12, T. 20 N., R. 3 E., M.D.)
	COPPER AND ZINC
6	Big Bend (Evening Star) (SE¼ sec. 8, T. 21 N., R. 5 E., M.D.)
	GOLD
7	Bader Brothers (SE¼ sec. 26, T. 23 N., R. 3 E., M.D.)
8	Banner (NW¼ sec. 34, T. 20 N., R. 4 E., M.D.)
9	Berry Hill (E½E½ sec. 28, T. 21 N., R. 5 E., M.D.)
10	Bragstresser (SE¼NE¼, lot 42, sec. 12, T. 20 N., R. 7 E., M.D.)
11	Bloomer Hill (NE¼ sec. 33, T. 21 N., R. 4 E., M.D.)
12	Blue Hog (SE¼ sec. 19, NE¼ sec. 30, T. 22 N., R. 4 E., M.D.)
13	Carlisle (sec. 25, T. 20 N., R. 6 E., M.D.)
14	Cascal (Dutch, Mammoth, Magalia) (W½ sec. 25; N½NW½ sec. 26; E½NW¼ sec. 35, T. 23 N., R. 3 E., M.D.; sec. 1, T. 22 N., R. 3 E., M.D.)
15	Cherokee Flat Blue Gravel (SW¼SW¼ sec. 13, T. 21 N., R. 4 E., M.D.)
16	Coutolenc (lot 4, SW¼ sec. 36, T. 24 N., R. 3 E., M.D.)
17	Cory & Strong (E½ sec. 16, T. 24 N., R. 4 E., M.D.)
18	Dix drift mine (S½ sec. 22, T. 24 N., R. 3 E., M.D.)
19	El Monte (Toadtown) (SW¼ sec. 36, T. 24 N., R. 3 E., M.D.)
20	Emma (Anaheim) drift mine (secs. 14, 15, and 23, T. 23 N., R. 3 E., M.D.)
21	Emma No. 2 placer (SE¼ sec. 10, T. 23 N., R. 3 E., M.D.)
22	Ethel (N½ sec. 3, T. 22 N., R. 3 E., M.D.)
23	Expedition (lot 13, No. 1) (SW¼ sec. 13, T. 20 N., R. 7 E., M.D.)
24	Gerli Mining Company [illegible] (S½ sec. 19, N½ sec. 30, T. 23 N., R. 4 E., M.D.; E½NE¼ sec. 25, T. 23 N., R. 3 E., M.D.)
25	Gold Bank Consolidated (Forbestown Consolidated Gold Mines) (lots 41, 48, 49, and 50, SE¼ sec. 2; NE¼ sec. 11; sec. 1; and sec. 12, T. 19 N., R. 6 E., M.D.)
26	Golden Summit Placer (SE¼NE¼, NE¼SE¼, W½SE¼, E½SW¼, SE¼ sec. 20, T. 25 N., R. 5 E., M.D.)
27	Gold Hill Dredging Company (sec. 10, T. 18 N., R. 3 E., M.D.)
28	Gold Mountain (NW¼ sec. 28, T. 25 N., R. 4 E., M.D.)
29	Hupp placers (NW¼ sec. 1; E½SW¼ and N½ sec. 2, T. 23 N., R. 3 E., M.D.)
30	Indian Springs (SW¼ sec. 3; NW¼ sec. 10, T. 22 N., R. 3 E., M.D.)
31	Inskip mining claim (SE¼SW¼ sec. 29, NE¼SW¼ sec. 32, T. 25 N., R. 4 E., M.D.)
32	I X L quartz ledge (NW¼ sec. 20, T. 22 N., R. 4 E., M.D.)
33	Jackpot (Golden Pearl) (SW¼ sec. 32, T. 22 N., R. 4 E., M.D.)
34	[illegible] Hill mine (W½ sec. 21; SE¼ sec. 18, T. 23 N., R. 3 E., M.D.)
35	Keystone & Golden Fisher (lot 60, E½SE¼SW¼; W½SW¼SE¼ sec. 3, T. 19 N., R. 6 E., M.D.)
36	Kickapoo Mining Claim (lot 38, sec. 17, T. 20 N., R. 7 E., M.D.)
37	Lancha Plana Gold Dredging Company (sec. 33, T. 22 N., R. 2 E., M.D.)
38	Lewis mine (secs. 2 and 11, T. 19 N., R. 6 E., M.D.)
39	Lucky John (SW¼SW¼ sec. 2, NW¼ sec. 11, T. 22 N., R. 3 E., M.D.)
40	Lydia placer (lot 3, sec. 36, T. 24 N., R. 3 E., M.D.)
41	Magalia (Perschbaker) mine (SE¼ secs. 13 and 24, T. 22 N., R. 3 E., M.D.)
42	Mammoth Gold Bank Consolidated (lots 41, 48, 49, and 50, secs. 2 and 11, T. 19 N., R. 6 E., M.D.)
43	McHugh prospect (SE¼SW¼ sec. 36, T. 24 N., R. 3 E., M.D.)
44	Mineral Slide (Magalia Consolidated) (S½ sec. 3, N½ sec. 10, T. 22 N., R. 3 E., M.D.)
45	Morris Ravine (Butterfly, Goodall & Pickard) (sec. 29, T. 20 N., R. 4 E., M.D.)
46	Mountain House drift prospect (center sec. 4, T. 21 N., R. 6 E., M.D.)
47	Mishel Lode & [illegible] mine (lots 1, 4, and 5, sec. 16, T. 20 N., R. 4 E., M.D.)
48	Paggel drift mine (S½ sec. 16, T. 24 N., R. 3 E., M.D.)
49	Oro Fino (secs. 10 and 11, T. 23 N., R. 3 E., M.D.)
50	Oroville Gold Dredging Company (sec. 4, T. 18 N., R. 3 E., M.D.)
51	Phoenix (lot 41, sec. 28, T. 19 N., R. 5 E., M.D.)
52	Pine Grove (Gold Bank Consolidated) (lots 41, 48, 49, and 50, sec. 11, T. 19 N., R. 6 E., M.D.)
53	Pitts (Old Bader, Henry & Newman) mine (secs. 1 and 2, T. 22 N., R. 3 E., M.D.)
54	Porter mine (secs. 17 and 20, T. 22 N., R. 4 E., M.D.)
55	Princess (SE¼ sec. 12, NE¼ sec. 13, T. 23 N., R. 3 E., M.D.)
56	Rainbow (SE¼NW¼ and E½SE¼ sec. 29, T. 22 N., R. 4 E., M.D.)
57	Red Hill (secs. 19 and 30, T. 22 N., R. 4 E., M.D.)
58	Potter Boulder drift mine (N½SW¼ sec. 20, T. 22 N., R. 4 E., M.D.)
59	Royal (Best, Robinson) drift mine (SW¼ secs. 21 and 34, T. 24 N., R. 3 E., M.D.; sec. 4, T. 23 N., R. 3 E., M.D.)
60	Sherman (Allen, McLeod) mine (W½ sec. 13, T. 24 N., R. 3 E., M.D.)
61	Silver Moon (Porphyry Fault group) (S½NW¼ sec. 18, T. 23 N., R. 4 E., M.D.)
62	Southern Cross (SE¼ sec. 32, T. 20 N., R. 6 E., M.D.)
63	Springer Consolidated (Matteson) Mining Company (E½ sec. 14, T. 24 N., R. 3 E., M.D.)
64	Stauffer (Joe J. Campbell) placer mine (SW¼ sec. 1, SW¼W½NW¼ sec. 12, E½NW¼ sec. 13, T. 23 N., R. 3 E., M.D.)
65	Sunrise mine (secs. 4, 5, 6, and 7, T. 21 N., R. 5 E., M.D.; secs. 1, 2, and 12, T. 21 N., R. 4 E., M.D.; sec. 23, T. 22 N., R. 4 E., M.D.)
66	Triumph No. 1 & No. 2 (N½ sec. 22, T. 20 N., R. 7 E., M.D.)
67	Triumph Extension (S½ sec. 13, T. 20 N., R. 7 E., M.D.)
68	Willard Consolidated quartz mine (SW¼NE¼ sec. 20, T. 22 N., R. 4 E., M.D.)
69	William George lode (SE¼SE¼ sec. 2, NE¼NE¼ sec. 11, T. 19 N., R. 6 E., M.D.)
70	Wyoming (Black Diamond) (N½ sec. 14, T. 24 N., R. 3 E., M.D.)
71	Yuba No. 1 dredge (sec. 13, T. 18 N., R. 3 E., M.D.)
72	Yuba No. 2 dredge (sec. 13, T. 18 N., R. 3 E., M.D.)
73	Yuba No. 2 dredge (sec. 15, T. 18 N., R. 2 E., M.D.)
	LEAD
74	Bonanza King prospect (sec. 16, T. 25 N., R. 5 E., M.D.)
	MINERAL PAINT
75	Ochre No. 1 & Ochre No. 2 (W½SE¼ sec. 6, T. 23 N., R. 4 E., M.D.)
	MINERAL SPRINGS
76	Richardson Springs (sec. 11, T. 23 N., R. 2 E., M.D.)
	SAND AND GRAVEL
77	Butte County Gravel Plant (sec. 15, T. 18 N., R. 3 E., M.D.)
78	Butte Creek [illegible] Rock Company (secs. 4 and 5, T. 21 N., R. 1 E., M.D.)
79	Central Sand and Gravel Plant (sec. 12, T. 20 N., R. 2 E., M.D.)
80	Henry J. Kaiser Company (secs. 25, 35, and 36, T. 18 N., R. 3 E., M.D.)
81	[illegible] gravel pit (sec. 24, T. 21 N., R. 3 E., M.D.)
82	Kennedy gravel pit (secs. 18 and 19, T. 22 N., R. 3 E., M.D.)
83	Miller Martin pit (sec. 1, T. 20 N., R. 2 E., M.D.)
84	Ray Mathews (SW¼ sec. 31, T. 18 N., R. 3 E., M.D.)
85	Sake & Sanders rock pit (NE¼ sec. 23, T. 23 N., R. 3 E., M.D.)
86	Strauss Sand & Gravel Company (sec. 8, T. 20 N., R. 2 E., M.D.)
87	L. L. Wilson (sec. 36, T. 22 N., R. 1 E., M.D.)
	TALC
88	McIntire talc claim (sec. 32, T. 22 N., R. 5 E., M.D.)

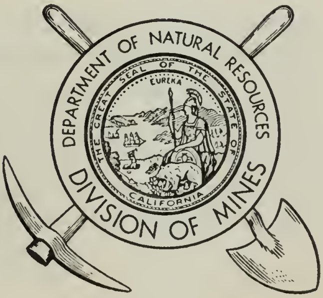
PHYSICAL SCIENCES

STATE OF CALIFORNIA
EARL WARREN, GOVERNOR
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

Vol. 45 OCTOBER 1949 No. 4

CALIFORNIA JOURNAL
OF
MINES AND GEOLOGY



Centennial Issue

STATE OF CALIFORNIA
EARL WARREN, Governor
DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
OLAF P. JENKINS, Chief

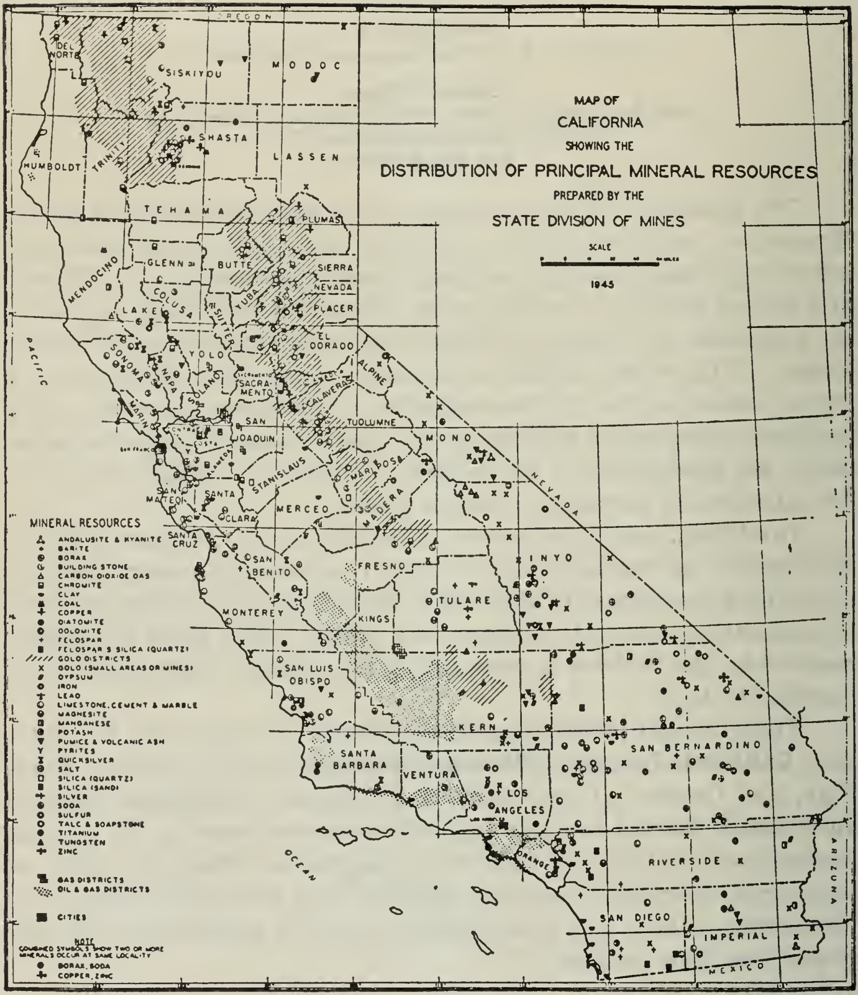
Headquarters
Third Floor, Ferry Building, San Francisco 11

District Offices
State Building, 217 West First Street, Los Angeles 12
631 J Street, Sacramento 14
Box 445, Redding

The Division of Mines maintains at its headquarters offices in San Francisco a technical library containing several thousand books and scientific journals on geology, mining, mineralogy, chemistry, metallurgy, and related subjects; a reading room containing periodicals devoted to the petroleum and mining industries, and newspapers from the mining centers of the state; exhibits of minerals, rocks, mine models, etc.; a service laboratory for the determination of California minerals; and a conference room with a mining engineer in attendance to serve the public and to sell publications of the Division. Publications are also sold at the Los Angeles and Sacramento district offices.

In addition to oral conferences in the offices of the Division of Mines, information concerning the mineral resources, mineral industry, geology, and mining operations of California is distributed to the public by means of publications, monthly releases, and letters. Each letter of inquiry received by the Division is answered by the technical staff member best qualified to do so.

The principal publications of the Division of Mines are the quarterly **California Journal of Mines and Geology,** issued in January, April, July, and October of each year, and a series of **Bulletins. Mineral Information Service** is a monthly news release concerning the mineral resources and industry of California, designed to inform the public of discoveries, operations, markets, statistics, and new publications. It is distributed without cost upon request. A list of publications will also be sent free upon request.


MAP OF
CALIFORNIA
SHOWING THE
DISTRIBUTION OF PRINCIPAL MINERAL RESOURCES
PREPARED BY THE
STATE DIVISION OF MINES
SCALE
1945
MINERAL RESOURCES
ANDALUSITE & KYANITE
BARITE
BORAX
BUILDING STONE
CARBON DIOXIDE GAS
CHROMITE
CLAY
COAL
COPPER
DIATOMITE
DOLOMITE
FELDSPAR
FELDSPAR & SILICA (QUARTZ)
GOLD DISTRICTS
GOLD (SMALL AREAS OR MINES)
GYPSUM
IRON
LEAD
LIMESTONE, CEMENT & MARBLE
MAGNESITE
MANGANESE
POTASH
PUMICE & VOLCANIC ASH
PYRITES
QUICKSILVER
SALT
SILICA (QUARTZ)
SILICA (SAND)
SILVER
SODA
SULFUR
TALC & SOAPSTONE
TITANIUM
TUNGSTEN
ZINC
GAS DISTRICTS
OIL & GAS DISTRICTS
CITIES
NOTE
COMBINED SYMBOLS SHOW TWO OR MORE MINERALS OCCUR AT SAME LOCALITY
BORAX, SODA
COPPER, ZINC
OREGON
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
MENDOCINO
GLENN
BUTTE
SIERRA
NEVADA
COLUSA
YUBA
PLACER
LAKE
SUTTER
EL DORADO
YOLO
SONOMA
NAPA
SOLANO
SACRAMENTO
ALPINE
AMADOR
CALAVERAS
MARIN
SAN JOAQUIN
TUOLUMNE
MONO
CONTRA COSTA
ALAMEDA
San Francisco
STANISLAUS
MARIPOSA
SAN MATEO
SANTA CLARA
MERCED
MADERA
SANTA CRUZ
SAN BENITO
FRESNO
INYO
NEVADA
MONTEREY
TULARE
KINGS
PACIFIC
SAN LUIS OBISPO
KERN
SAN BERNARDINO
SANTA BARBARA
VENTURA
LOS ANGELES
OCEAN
ORANGE
RIVERSIDE
ARIZONA
SAN DIEGO
IMPERIAL
MEXICO

CONTENTS

Page

Geology of Limestone near Sonora, Tuolumne County, California, by George R. Heyl and John H. Wiese ---------- 509

Geology of Limestone near Gazelle, Siskiyou County, California, by George R. Heyl and George W. Walker ---------- 514

Minerals of California—Supplement No. 1 to Bulletin 136, by Joseph Murdoch ---------- 521

Water-Flooding as a Method of Increasing California Oil Production—Part 3, by Wilbur H. Somerton ---------- 541

Materials of Inorganic Mineral Origin Used in the Rubber Industry, by Erle C. Zimmerman ---------- 553

Division of Mines Publications Issued May 1, 1949 to October 1, 1949 562
Index to Volume 45 ---------- 563

CENTENNIAL SUPPLEMENT

The Elephant as They Saw It, by Elisabeth L. Egenhoff

PLATES

Plate 24. Geologic map and structure sections of limestone deposits at Black Leg Creek, Sonora, Tuolumne County ---------- In pocket

25. Geologic map of a part of the 265 level, U. S. Lime Products Corp. mine, Sonora, Tuolumne County ---------- In pocket

26. Geologic map and structure sections of limestone deposits near Gazelle, Siskiyou County ---------- In pocket

2—99478-M

GEOLOGY OF LIMESTONE NEAR SONORA, TUOLUMNE COUNTY, CALIFORNIA *

By George R. Heyl ** and John H. Wiese **

OUTLINE OF REPORT

Page
Introduction ---------- 509
Location and accessibility ---------- 509
Topography and drainage ---------- 510
General geology ---------- 510
Limestone deposits ---------- 510
  Lithologic and chemical characteristics ---------- 510
  Geologic structure ---------- 511
  Economic geology ---------- 512

Illustrations

Plate 24. Geologic map and structure sections of limestone deposits at Black Leg Creek, Sonora, Tuolumne County ---------- In pocket
25. Geologic map of part of the 265 level, U. S. Lime Products Corp. mine, Sonora, Tuolumne County ---------- In pocket

INTRODUCTION

A belt of crystalline limestone containing discontinuous layers of schist extends northwest through the town of Sonora, Tuolumne County, California. The most extensive limestone area is adjacent to Black Leg Creek, approximately three-quarters of a mile southeast of the town of Sonora. The belt is approximately 2 miles long and near its northern end is nearly 2,000 feet wide. Some limestone zones in the belt are commercially valuable because they are composed almost wholly of calcium carbonate, but most of the limestone contains too much magnesium carbonate. All the limestone is crystalline, ranging from moderately fine grained to moderately coarse grained.

The limestone was examined by G. R. Heyl during November and December 1947. An enlargement of parts of the Standard and Sonora quadrangle maps of the U. S. Geological Survey was used as a base for the accompanying geologic map (pl. 24). Mine maps of the U. S. Lime Products Corporation were used as a base for the underground mapping. A memorandum report by Heyl was the basis for the present report, which was prepared by John H. Wiese.

Messrs. Stanley L. Arnot and Walter A. Stinson Jr. of the U. S. Lime Products Corporation showed a lively interest in the work and generously cooperated with Heyl during the field work. Dr. Olaf P. Jenkins of the California State Division of Mines kindly offered valued suggestions.

The following description of the limestone emphasizes the geologic factors important in its mining and utilization, especially the chemical and lithologic characteristics of the limestone.

LOCATION AND ACCESSIBILITY

The limestone belt is crossed by the Sierra Railroad, which extends from Tuolumne City, about 7 miles east of Sonora, to Oakdale, near the eastern side of the San Joaquin Valley. The limestone belt is also accessible from the west and northwest by several all-weather paved highways. The climate is moderate; the winters are mild, and work may be done outdoors throughout the year.

---

* Published by permission of the Director, U. S. Geological Survey; manuscript submitted for publication April 29, 1949.

** Geologist, U. S. Geological Survey.

TOPOGRAPHY AND DRAINAGE

The limestone belt is reflected topographically as an elongate lowland bounded on either side by higher, generally more rugged areas underlain by schist and quartzite. The low, open limestone country ranges in altitude from 1,500 to 1,900 feet. In most places the relief is low, the maximum within the area mapped being about 650 feet. Of especial interest are the old sinkholes in the limestone near the southern end of the belt. These formed long before the present erosion period and became filled with auriferous gravels which have been mined.

The limestone belt is drained by tributaries of Sonora and Sullivan Creeks, both major branches of Woods Creek, which in turn discharges into the Tuolumne River. The larger streams of the area flow throughout the year, the smaller ones only during winter and spring.

GENERAL GEOLOGY

The limestone in the vicinity of Sonora is part of the ''Bed-rock series'' of the Sierra Nevada,[1] a thick sequence of metamorphosed sedimentary and volcanic rocks. The rocks have been intensely folded and faulted, and have been intruded by dikes and larger masses of several varieties of igneous rock. Within the area mapped for this report, the most common rock types are limestone, ''amphibolite'' schist, mica schist, quartzite, and granodiorite.

The limestone belt is bounded on the west by ''amphibolite'' schist derived from volcanic rocks, and on the east by siliceous mica schist and quartzite. The ''amphibolite'' schist generally contains pale-green to colorless amphibole, chlorite, epidote, feldspar, and in places quartz. Some mica schist and quartzite are also found within the limestone belt. South toward the contact of a granodiorite mass, which is a part of a major westerly extension of the batholithic core of the Sierra Nevada, the ''amphibolite'' schist grades into mica-amphibole schist and mica-feldspar-quartz schist, but the limestone apparently is not more intensely metamorphosed toward the granodiorite.

LIMESTONE DEPOSITS

Lithologic and Chemical Characteristics

All the limestone within the area studied is crystalline, and grains are large enough to be readily seen with the unaided eye. Typical of the limestone is its banding. The bands are a fraction of an inch to several inches thick, and they consist of more or less parallel, alternate layers of dark-gray and pale-gray or white limestone. These bands are parallel to the boundaries of lithologic units and may be either bedding or the result of flowage during folding. Locally, differential weathering along the bands makes the layering conspicuous. In most places, however, the weathered limestone is characterized by the irregularity of solution pits and solution channels.

The limestone is of two major types: (1) those made up chiefly of calcium carbonate ($CaCO_3$) and containing not more than 5 percent of other substances; and (2) those containing an appreciable amount—5 to 30 percent—of other substances, mostly magnesium carbonate ($MgCO_3$).

---

[1] Turner, H. W., and Ransome, F. L., U. S. Geol. Survey Geol. Atlas, Sonora folio (no. 41), pp. 3-6, 1897.

In general, these two types can be distinguished in the field by the marked difference in grain size. The magnesian limestone is finer grained, most of the individual grains ranging in diameter from 0.05 to 0.3 of a millimeter. In the limestone composed of nearly pure calcium carbonate, the grains range from 0.5 to 5 millimeters.

Most of the high-calcium limestone is found along two zones in the belt, which otherwise consists mainly of magnesian limestone. The zone being mined at present is close to the east side of the belt, along Black Leg Creek, and the other is close to the west side of the belt, near Sullivan Creek.

The chemical compositions summarized in table 1 probably are typical of the limestone of the belt. The limestone that was being mined in 1947 is represented by samples 2, 3, and 4; those of the western zone are represented by sample 1, and the magnesian limestone by sample 5. The high-calcium limestone contains 95 percent or more of calcium carbonate, and the chief impurities are small amounts of magnesium carbonate, silica, and alumina. Though the analyses reveal only a trace of sulfur, freshly broken limestone generally smells of hydrogen sulfide.

The magnesian limestone that was analyzed contains approximately 30 percent of magnesium carbonate. Other analyses, if made, would probably show that some limestone in the area contains even more magnesium carbonate; possibly some would approach the theoretical composition of dolomite ($MgCO_3$=45.65 percent, $CaCO_3$=54.35 percent).

Geologic Structure

Beds in the limestone within the belt strike northwest, and in most places dip between 75° E. and 75° W. The beds in the metamorphic rocks roughly parallel the contact with the granodiorite that lies to the east. The planar structure in the border facies of the granodiorite is also conformable with the contact. Most linear structures in the limestone and in the schists plunge to the southeast, but the attitude at any locality should be determined carefully, for in some limestone deposits of the Mother Lode district the plunge of lineation is a direct guide to the rake of commercial-grade rock.

Joints (not shown on pl. 24 or 25) are spaced a few inches to a few feet apart. Two particularly prominent joint sets occur approximately at right angles to the banding in the limestone. One set dips vertically or steeply southeast, and the other set dips 5° to 30° NW. A third set, less prominent, is parellel to the banding. Slickensides were seen on the joints that lie approximately at right angles to the banding, but the amount of movement on these joints is probably small. Dikes of diorite, diorite porphyry, granodiorite, and lamprophyre, a few inches to several feet thick, intrude joints of all three sets.

Only a few small faults are shown on plate 25, but there may be many more, especially strike faults and bedding faults. For example, a prominent feature in the mine of the U. S. Lime Products Corporation is a zone of faulting that strikes N. 15° to 25° W., parallel to the beds, though in dip the zone cuts beds at an angle of 5° to 10°; this zone marks the west boundary of a layer of dolomitized and pyritized limestone (see pl. 25). This may be a fault of considerable displacement, but it can be observed and mapped only in the mine workings where exposures are good. Similar fault zones might be found if the entire limestone belt were as well exposed.

Table 1. Partial analyses of the limestone.

(Analyzed by P. T. Bee, Chief Chemist, Abbot A. Hanks, Inc., San Francisco, California)

Sample	*1*	*2*	*3*	*4*	*5*
CaO	54.42	54.52	53.70	53.50	38.01
MgO	0.61	0.61	1.47	1.13	14.00
Fe_2O_3	0.09	0.04	0.08	0.12	0.21
Al_2O_3	0.41	0.36	0.32	0.37	0.55
SiO_2	0.92	0.95	0.59	1.43	2.07
S	Trace	Trace	Trace	Trace	Trace
P	0.031	0.037	0.041	0.027	0.061
$CaCO_3$ (calculated)	97.18	97.36	95.89	95.54	67.88
$MgCO_3$ (calculated)	1.28	1.28	3.09	2.37	29.41

1. Sample represents a 105-foot width (and stratigraphic thickness), collected from outcrops approximately 200 feet north of Sullivan Creek, near west edge of limestone belt. Near Sonora, California.
2. Sample represents a 51-foot width (and stratigraphic thickness), collected in underground chamber adjacent to central quarry of U. S. Lime Products Corporation. Near Sonora, California.
3. Sample represents a 110-foot width (and stratigraphic thickness), collected from footwall zone approximately 270 feet north of shaft on the 265 level of U. S. Lime Products Corporation mine. Near Sonora, California.
4. Sample represents a 110-foot width (and stratigraphic thickness), collected from hanging-wall zone approximately 280 feet northeast of shaft on the 265 level of U. S. Lime Products Corporation mine. Near Sonora, California.
5. Magnesian limestone. Sample across a 45-foot width, collected from east quarry of U. S. Lime Products Corporation mine. Near Sonora, California.

Another zone of faulting is in the southern part of the U. S. Lime Products Corporation mine (pl. 25). The most prominent fault of the zone is reverse; it strikes northeast and dips 34° NW. Associated with it are subsidiary faults that strike northwest and dip southwest. This zone of faulting is present at all levels of the mine, through a vertical distance of at least 300 feet.

Economic Geology

In 1947 limestone was exploited only at the U. S. Lime Products Corporation mine, located in the central part of the area, about a mile south of Sonora. Six limestone quarries in the belt were idle (see pl. 24), and many other sites favorable for quarrying operations have never been developed. The mine of the U. S. Lime Products Corporation consists of a vertical shaft with levels at 120, 170, 215, 265, and 320 feet. Two wide zones of high-calcium limestone were being mined, and a third zone which lies immediately west of these has been worked in the past. Mining was by the room-and-pillar method; underground, most of the rock is moved by slushers and in chutes. A large processing plant is adjacent to the shaft collar. The products shipped include both crude and calcined varieties of high-grade limestone and low-iron dolomite. The leading product in 1947 was limestone for glass manufacture.

The detailed geology of part of the 265 level is shown on plate 25. The beds in this section of the mine dip steeply northeastward. Schist and quartzite bound the limestone on the east and form the hanging wall. Three zones of high-calcium limestone are penetrated. The westernmost, locally called ''soft rock,'' was not being used in 1947 because certain physical characteristics developed on calcining make it less amenable to treatment in the processing plant. The other two zones, known as ''chemical grade,'' were both mined. These two zones are separated by a zone of pyrite-bearing dolomitic limestone, which contains too much iron and magnesium for commercial uses.

Of practical significance in the mining is the presence or absence of dikes of diorite, diorite porphyry, granodiorite, and lamprophyre in the limestone. Where these are closely spaced the ground is unfavorable for large-scale mining, because small amounts of the dike rock mixed with the broken limestone make the product unfit for many specialized uses.

In summary, the Sonora limestone belt is favorable for the production of high-quality limestone for industrial purposes. High-calcium and magnesian limestone is available in ample quantities. In the large-scale mining of limestone of chemical grade, however, avoidance of dikes and magnesia-rich zones is necessary. Markets are close at hand and transportation is good.

GEOLOGY OF LIMESTONE NEAR GAZELLE, SISKIYOU COUNTY, CALIFORNIA *

By George R. Heyl ** and George W. Walker **

OUTLINE OF REPORT

	Page
Introduction	514
Location and accessibility	514
Topography and drainage	515
Geology	515
Stratigraphy	517
Structure	518
Limestone deposits	519
Lithology and chemical composition	519
Economic evaluation	520

Illustrations

Figure 1.	Index map showing location of area covered in this report	515
Figure 2.	View northwest up valley of North Branch of Willow Creek	516
Plate 26.	Geologic map and structure sections of limestone deposits near Gazelle, Siskiyou County, California	In pocket

INTRODUCTION

Limestone, high in calcium carbonate, low in magnesium carbonate, and containing negligible amounts of impurities, crops out in an area a few miles west of Gazelle, Siskiyou County, California. During the period October 8 to October 22, 1947, the geology of this area was mapped by G. R. Heyl: the area was visited and additional mapping was done by G. W. Walker in October 1948. Aerial photographs were used as a base for geologic mapping. The topographic data used in the construction of geologic structure sections were taken from the U. S. Geological Survey Yreka quadrangle map and the Klamath National Forest map, U. S. Forest Service.

This report describes the geologic structure of the limestone, which is of particular interest, and it also describes the lithology and the chemical composition of the limestone. Sincere thanks are due Dr. Olaf P. Jenkins and Mr. C. V. Averill of the California State Division of Mines, who have contributed valuable suggestions, and to members of the U. S. Geological Survey who critically reviewed this report.

Location and Accessibility

The area that contains limestone of economic importance is in secs. 6 and 7, T. 42 N., R. 6 W., and sec. 12, T. 42 N., R. 7 W., M. D.[1] The limestone area, 2 to 5 miles west and southwest of Gazelle, is on the hills surrounding and in the valley of the North Branch of Willow Creek, a tributary of the Shasta River. The area is conveniently reached by an unsurfaced road which is open throughout the year.

Gazelle is on U. S. Highway 99, one of the main roads connecting population centers of northern California with those of Oregon. The Southern Pacific Railroad maintains a station at Gazelle, on its line between San Francisco and Portland.

---

* Published by permission of the Director, U. S. Geological Survey; manuscript submitted for publication April 13, 1949.

** Geologist, U. S. Geological Survey.

[1] References to sections were obtained from the Klamath National Forest map and from claim markers. Section lines are not shown on the geologic map, because no corners were located in the field.

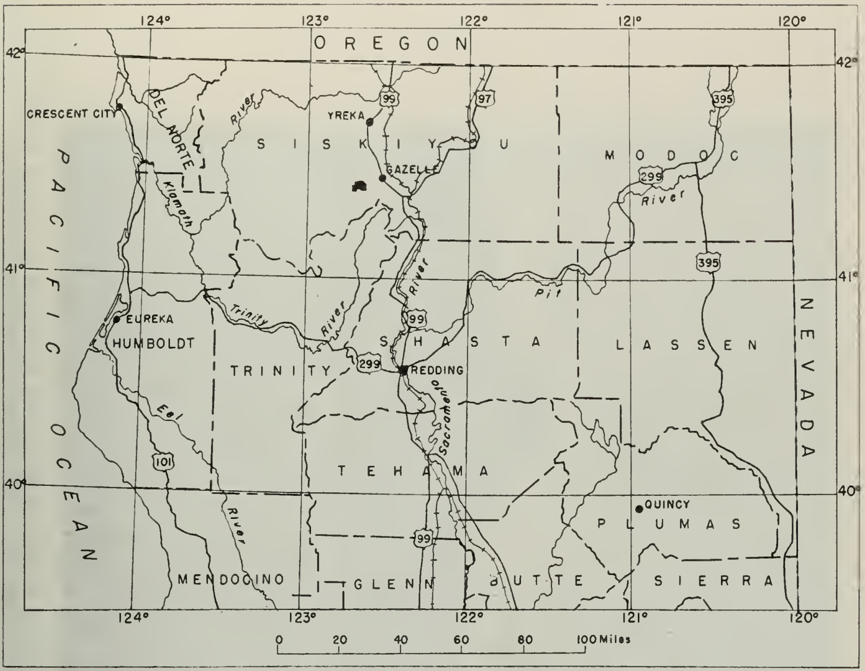


FIGURE 1. Index map showing location of area (black) covered in this report.

Topography and Drainage

The limestone area ranges in altitude from approximately 2,950 feet to 4,766 feet, thus the maximum relief is about 1,800 feet. The valley of the North Branch of Willow Creek is a gently rolling plain that widens toward the east. It is surrounded by rugged hills in which the resistant limestone generally develops prominent scarps and high cliffs (see fig. 2). On many north-facing slopes, however, the limestone weathers to more subdued forms, and conspicuous scarps are less common.

The streams within the area are intermittent, flowing only during and for a short time after the wet winter season. Water for quarrying and other purposes can be readily obtained from shallow wells, for in most parts of the district the water table is near the surface.

GEOLOGY

The mapped area lies within and near the eastern edge of the Klamath Mountain geologic province, where the lavas of the Cascade Range are contiguous with Paleozoic rocks of the province. Rocks of the area are of two distinct groups, a younger group that consists of lava and unconsolidated rock debris, and an older group made up of various consolidated sedimentary rocks intruded by small bodies of diorite and quartz diorite (see pl. 26).

The consolidated sedimentary rocks of the older group are part of the Paleozoic sequence that underlies a wide region in the eastern Klamath Mountains of central Siskiyou County. Within the area mapped this sequence consists of gray and red shale, gray and black chert, gray siltstone, graywacke, sandstone, conglomerate, and limestone. Lateral gradation from one lithologic type to another is not uncommon; the chert,

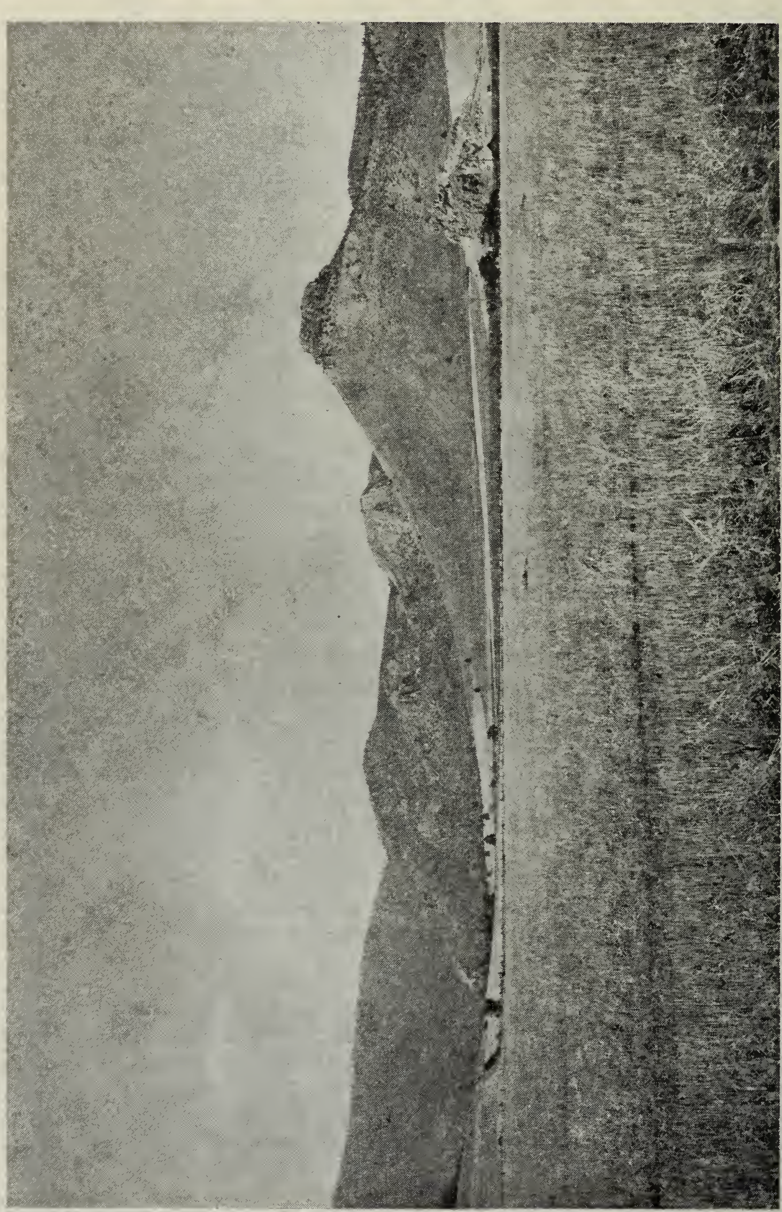


FIGURE 2. View northwest up the valley of the North Branch of Willow Creek, showing surrounding hills with bold outcrops of limestone. Electro Lime and Chemical Company quarries located on small knoll at right side of picture.

the conglomerate, and in places the limestone occur as lenses or discontinuous beds in the shale and sandstone. All older strata have been upturned, folded, and faulted, and locally intruded by small bodies of diorite and quartz diorite, truncated by erosion, and finally overlain unconformably by rocks of the younger group. Basalt flows of late Tertiary or Quaternary age and alluvium, talus debris, and related unconsolidated deposits of Quaternary age constitute the rocks of the younger group.

Stratigraphy

The limestone in the area occurs as a thick, fairly continuous unit, herein called the main limestone, and as discontinuous lenses. The main limestone forms cliffs and bold outcrops which are prominent features of the landscape. In the southern part of the area the main limestone is more than 200 feet thick, whereas the limestone capping on North Peak is slightly less than 200 feet. Most of the limestone is thick bedded; interbedded layers of other material are few and thin. At several localities the limestone includes an intraformational carbonate-cemented limestone conglomerate. Lenses of limestone are present in the rocks beneath the main limestone unit. Most of the lenses are restricted in areal extent (see pl. 26) and occur 35 to 225 feet stratigraphically below the base of the main limestone.

The sedimentary section below the main limestone is not everywhere the same. In the western half of the area beds of medium- to coarse-grained conglomerate underlie the limestone at most places. The conglomerate contains abundant rounded pebbles of gray and black chert and white quartz, cemented by brown siliceous material. About 1,500 to 2,000 feet southwest of North Peak, this conglomerate grades upward through conglomerate with carbonate cement and limestone pebbles to the intraformational conglomerate that is associated with the main limestone unit.

Beneath the limestone in the eastern half of the area, a thin unit of dark-colored sandstone is locally present, similar in lithology to the conglomerate. A lateral gradation from the conglomerate on the west to the sandstone on the east seems to explain this change, and suggests that the source of these sediments lay to the west. Where neither the conglomerate nor the sandstone is present, the limestone overlies a sequence of gray and red shale, gray and black chert, gray siltstone, and fine-grained sandstone with some interstitial carbonate.

In many places the bedding of the main limestone is discordant with the strata immediately underlying it. Although this discordant contact might be interpreted as an erosional unconformity, field evidence suggests that locally faulting between the competent limestone and the underlying incompetent strata took place at the time of regional folding. Direct evidence of faulting can be seen locally along the base of the limestone scarp that extends southward from North Peak; the limestone apparently was thrust eastward relative to the underlying crumpled shale and chert.

The beds above the main limestone are not well exposed except along the south-central margin of the area, where there are large massive outcrops of gray chert in which stratification is obscure. The soil in this vicinity contains abundant fragments of chert and gray shale, suggesting that the rocks in this area are similar lithologically to the rocks beneath the limestone.

The rocks of the younger group include basalt flows of late Tertiary or Quaternary age and unconsolidated alluvium and landslide debris of Quaternary age. These rocks have not been noticeably disturbed by tectonic processes.

Basalt was observed in two places, one along the crest of a high ridge near the north margin of the area, the other close to the valley floor, about 1,000 feet south of the North Branch of Willow Creek. Slight differences in mineral composition and the relative position of the outcrop areas of these basaltic rocks—one area on a ridge and the other near the valley floor—suggest that they are separate and distinct basalt flows. The lava from both areas is dark-purplish gray to black, and weathers to shades of brown. At both localities minute crystals of plagioclase can be discerned with the aid of a hand lens, though in the lava on the ridge to the north, small yellow-green grains of olivine, with vitreous luster can be distinguished.

Other rocks of the younger group consist of unconsolidated alluvium, talus debris, slope wash, and landslide material. This unsorted rock waste is made up largely of material derived from the rocks of the older group.

Structure

The geologic structure of the area is illustrated by plate 26. The regional structure is dominated by two major anticlines and a broad, intervening syncline that has been broken by a series of high-angle faults. One anticline extends from a point about 6,500 feet south of the Electro Lime and Chemical Company quarries northwest toward North Peak; the other anticline is in the southwest corner of the area and extends northeast across the North Branch of Willow Creek. The axes of the smaller folds, with one minor exception, bear N. 10° W. to N. 30° E., and plunge gently. The folds are open, and on the limbs the beds dip moderately to gently.

The two major anticlines are separated by a zone of high-angle faulting that trends approximately north. Numerous minor faults within this zone can be seen locally, but their position and their relationship to major structures is obscure, particularly where these faults cut the sediments beneath the limestone. Approximately 4,000 feet east of the zone of high-angle faulting, and roughly parallel to it, is a vertical fault. This fault has strongly slickensided walls, the slickensides indicating that the latest movement was approximately strike-slip, and that the west side moved southward.

The fault bounding the west flank of the major anticline in the southwest corner of the area has broken and displaced a syncline along its axial region. The fault shows reverse movement, the southeast side having moved upward.

About 500 feet south of North Peak there is a large erosional re-entrant in the limestone scarp. At the base of the limestone in this vicinity the rocks have been brecciated, crushed, and slickensided. The bedding above this zone is discordant with the bedding below, giving additional evidence for a low-angle fault. The faulting is local, and where evident, it has resulted in relationships that simulate an unconformity.

Joints occur both in the limestone and in the sedimentary rocks beneath the main limestone. The joints in the limestone are usually spaced a foot to tens of feet apart, whereas in the underlying rocks they are spaced a few inches to a foot apart. The two most prominent joint systems (not shown on map) strike respectively about N. 25° W., and N. 20° E., and dip both east and west at angles greater than 70°. A third system trends approximately east. Jointing, more than bedding, has controlled weathering and erosion of the limestone and locally has been of paramount importance in the development of scarps and cliffs.

Cleavage (not shown on map) is not an important feature in the area, but it was observed in slaty siltstone and shale, and in the argillaceous matrix of conglomerate. It is best developed in the strata underlying the limestone in the vicinity of North Peak, where it dips 80° to 90° E., and strikes N. 10° E., and N. 25° E. Along the southern margin of the area, cleavage in argillaceous conglomerate beneath the limestone zone dips 70° to 80° W., and also has a northeasterly strike.

LIMESTONE DEPOSITS

Lithology and Chemical Composition

Lithologically the limestone is nearly uniform throughout the area. The limestone is characteristically a fine-grained, compact, even-textured blue-gray rock that weathers to pitted and fluted light-gray surfaces. In most places the limestone is thick-bedded, though some of the smaller lenses, and locally the main limestone unit, have beds an inch to several inches thick. Narrow veinlets of white calcite cut the limestone in many places, but in general they are not a prominent feature. On careful examination with a hand lens minute crystals of calcite are disclosed in the very fine-grained groundmass of the limestone; near faults and areas of intense folding, grains of recrystallized calcite are larger and noticeably more plentiful.

Small lenses of chert-quartz conglomerate are present within the main limestone unit. In some localities this conglomerate has a siliceous cement (as in the small lenses shown near the south edge of pl. 26), but more commonly the matrix is calcite. Lenses of gray chert, as much as 5 feet thick, are also associated with the limestone. Such lenses are especially abundant in the southern part of the area.

Closely associated with the limestone, and in many places grading into it, is a medium- to coarse-grained intraformational conglomerate that contains angular and subangular fragments of blue-gray limestone embedded in a gray-white calcium carbonate cement. The conglomerate weathers to shades of gray and pale reddish brown. Lithologically the fragments are similar to the associated limestone, and it is likely that this conglomerate represents reworked lime mud that was deposited in shallow water. At some localities the conglomerate is present at the base of the main limestone, and in other places is higher within the limestone. The larger areas underlain by this conglomerate are delineated on the geologic map (see pl. 26).

The chemical composition of the limestone and of the limestone conglomerate with carbonate cement is shown by the analyses in table 1. Both these rock types are of commercial grade and can be included in the total limestone reserves of the area. In all the rocks analyzed, the calcium carbonate content exceeds 93.75 percent, and the magnesia content is very low. Samples taken at the Electro Lime and Chemical Company quarries, about a mile from the eastern edge of the area (see pl. 26), are high calcium limestone with impurities present in very small or negligible quantities. The samples taken elsewhere in the area show rock of good chemical quality, though a slightly lower percentage of calcium carbonate is characteristic.

Economic Evaluation

Development of the limestone reserves near Gazelle has been sporadic; only four small excavations have been worked at various times during periods of exploitation. Of the four limestone quarries, only the two in the eastern half of the area were in production during November 1947. These two quarries, located on the knoll of limestone 1,500 feet north of North Branch, are operated by the Electro Lime and Chemical Company of Gazelle. During 1947 the company was reported to be shipping about 200 tons of agricultural limestone per day, 125 tons of carbide rock per week and approximately 400 tons of rock per year for the manufacture of paper. In October 1948 the Electro Lime and Chemical Company quarries were temporarily closed down; however, stockpiled agricultural limestone was being shipped.

Mr. E. M. Greenwood, of Seattle and Gazelle, has made application for patents on 11 claims in sec. 12, T. 42 N., R. 7 W., and sec. 6, T. 42 N., R. 6 W., M. D. His claims cover much of the area that is most favorable for commercial exploitation; however, as of October 1948, no development work had been started.

Table 1. Analyses of limestone.

(Analyzed by P. T. Bee, Chief Chemist, Abbot A. Hanks, Inc., San Francisco, California)

	1	*2*	*3*	*4*	*5*
CaO	54.81	54.12	52.82	53.72	52.52
MgO	0.09	0.22	0.36	0.19	0.37
Fe_2O_3	0.14	0.29	0.36	0.28	0.43
Al_2O_3	0.25	0.17	0.67	0.30	0.69
SiO_2	1.13	1.96	2.64	2.06	4.21
S	Trace	Trace	Trace	Trace	Trace
P	0.001	0.002	0.001	0.001	0.001
$CaCO_3$ (calculated)	97.88	96.64	94.32	95.93	93.79

1. Limestone, sample across a 35-foot thickness in upper quarry of Electro Lime and Chemical Company; NE¼ sec. 8, T. 42 N., R. 6 W., M. D.
2. Limestone, sample across a 35-foot thickness in lower quarry of Electro Lime and Chemical Company; NE¼ sec. 8, T. 42 N., R. 6 W., M. D.
3. Limestone conglomerate with carbonate cement, composite grab sample from crest of ridge ¾ mile south of North Branch; NE¼ sec. 18, T. 42 N., R. 6 W., M. D.
4. Limestone, sample across a 50-foot thickness in quarry 750 feet north of North Branch; NW¼ sec. 7, T. 42 N., R. 6 W., M. D.
5. Limestone, sample across a 50-foot width in quarry 250 feet south of North Branch; SE¼ sec. 12, T. 42 N., R. 7 W., M. D.

Large reserves of good quality limestone, high in calcium carbonate, low in magnesium carbonate, and containing negligible amounts of sulfur and phosphorus, occur in the area. Overburden does not present a problem here, for it is either a few feet thick or lacking over most of the tracts containing limestone. Jointing within the limestone should minimize the problem and costs of breaking and quarrying the stone, although in some of the more massive outcrops, where joints are widely spaced, quarrying may prove costly.

The areas most suitable for the commercial exploitation of limestone are indicated on plate 26. In these areas quarries might be advantageously situated because the limestone is thick and of good quality, overburden is thin or absent, and the areas are easily accessible.

MINERALS OF CALIFORNIA—SUPPLEMENT NO. 1 TO BULLETIN 136 *

By Joseph Murdoch **

OUTLINE OF REPORT

Page
Introduction ---------- 521
Errata—Bulletin 136 ---------- 521
Descriptions of California minerals and mineral localities---------- 522
Bibliography ---------- 534
Serials consulted ---------- 534
References ---------- 535

INTRODUCTION

At the time that Bulletin 136, the current revision of *Minerals of California* was made, it was planned to issue, from time to time, supplements which would keep the work up to date. These supplements would further provide opportunity for correcting errors in Bulletin 136, as these came to light on inspection and use.

The amount of new literature on California minerals, and the number of new occurrences, since 1945, the closing date for entries in Bulletin 136, has already warranted the publishing of the first of these supplements, covering the years 1946, 1947, and 1948. It has been planned as a simple continuation of Bulletin 136, with the occurrence numbers and literature references running consecutively with those of the Bulletin. The principle has been continued of entering in the bibliography important references to California minerals, whether or not they are directly used in this supplement.

A list of errors so far discovered in Bulletin 136 is inserted here, and it is to be hoped that anyone observing additional errors or omissions will bring them to the attention of the writers so that they may be corrected in subsequent supplements.

ERRATA—BULLETIN 136

The following corrections should be made in Bulletin 136:

p. 9 For "Vossen," read "Vonsen."

p. 87 Celestite in Fish Mountains should be recorded as Fish Creek Mountains from *San Diego County*, instead of *Imperial County.*

p. 205 Melanterite, *Lake County*, Bradford occurrence should be listed as *2.*

p. 216 Monazite, *Riverside County*, reference no. 6 should be no. *1, San Diego County*, Fisher (1) p. 144.

p. 236 Powellite, *Kern County, 2*, under Wiese and Page, reference should read p. 39, not p. 36.

p. 238 Probertite, *Kern County*, add reference—Murdoch (17) p. 720.

p. 249 *Plumas County*, reference to diallage at La Porte should be deleted.

p. 281 Spodumene, *San Diego County* 5th and 6th line of paragraph, Gabriel et al. (42) should read Gabriel et al. (1).

p. 291 Szaibelyite, see camsellite, delete cross reference, and insert full description of szailbelyite, as given in the present paper.

p. 339 Creasey, S. C. (1) date should be 1946.

p. 400 Wiese, J. H. (and Page, L. R.), date of reference should be 1946.

p. 401 Wright, L. B., date of reference should be 1946.

---

* California Division of Mines Bulletin 136 was published under the authorship of Joseph Murdoch, and Robert W. Webb, University of California, Santa Barbara. Supplement No. 1 is also cooperative, but appears under single authorship because of preoccupation of Webb with other duties. Future supplements will appear under joint authorship. Manuscript submitted for publication April 1, 1949.

** Professor of Geology, University of California, Los Angeles, California.

DESCRIPTIONS OF CALIFORNIA MINERALS AND MINERAL LOCALITIES

ALUNITE

Sonoma County: 1, The occurrence of alunite at The Geysers has been described by Vonsen (6) p. 290 (confirming reference in Bulletin 136).

ALUNOGEN

Sonoma County: 1, Alunogen occurs as fibrous silky tufts in considerable abundance along Geyser Creek Canyon and other places at The Geysers, Vonsen (6) p. 290 (confirming reference in Bulletin 136).

AMPHIBOLES

SODA AMPHIBOLES

Glaucophane

Sonoma County: 3, Blue crystals of glaucophane occur with clinozoisite 2½ miles east of Valley Ford, S.M.B. (21318). Confirms Vonsen (p.c. '45).

Riebeckite

Tulare County: 1, Clusters of riebeckite needles up to ¼ inch in length, are found along a serpentine contact, in quartz-albite schist, southeast of Rocky Hill, Durrell (2) p. 93.

ANALCIME

Los Angeles County: 3, Clusters of small crystals of analcime are reported from the head of Brush Canyon, just west of Griffith Park Road, G. Neuerburg (p.c. '47).

ANATASE

Riverside County: Anatase occurs as a minor constituent of tonalite, in the tunnel south of Val Verde, R. W. Wilson (1) p. 124.

ARAGONITE

Monterey County: 1, Aragonite specimens from the cliff north of the mouth of Willow Creek are in the Division of Mines Museum S.M.B. (21307).

AURICHALCITE

Inyo County: 3, Specimen S.M.B. (21321) came from one mile east of Dodd Spring, Ubehebe Mining district.

AXINITE

Inyo County: 2, A specimen of axinite, with well developed crystals in epidote, S.M.B. (21320) from the south end of Butte Valley, Ubehebe Mining district, confirms the reference No. 2 in Bulletin 136.

BARITE

San Luis Obispo County: 2, A specimen of "sand barite" rosettes from the Caliente Range about 10 miles south of Taylor Springs, S.M.B. (21298), is from the occurrence reported by J. W. Eggleston (p.c. '36).

BENITOITE

San Benito County: 2, A second locality for benitoite, close to the original discovery, has been reported, Mineral Notes and News (1) p. 3.

BOEHMITE

Probably $Al_2O_3.H_2O$.

Microscopic orthorhombic plates, with good cleavage in one direction.

Riverside County: 1, Boehmite occurs at the Alberhill clay pits, associated with gibbsite, V. T. Allen (7) p. 1173.

BORNITE

Siskiyou County: 2, Bornite occurs with minor covellite and some chalcopyrite at the Preston Peak mine (sec. 22, T. 17 N., R. 5 E., H.), J. C. O'Brien (4) p. 428.

BOUSSINGAULTITE

Sonomo County: 1, Boussingaultite occurs as crusts and stalactites in Geyser Creek Canyon, The Geysers, Vonsen (6) p. 289; additional reference for record in Bulletin 136.

BROOKITE

Kern County: Minute spearlike crystals of brookite have been found in cavities of lava east of the highway in Red Rock Canyon, J. Murdoch (p.c. '47).

BRUCITE

Riverside County: Brucite, presumably pseudomorphous after periclase, is abundant at the Jensen Quarry, J. Murdoch (p.c. '47).

CALCITE

Tulare County: 1, Massive blue crystalline calcite, associated with scheelite, has been reported from the Consolidated Tungsten Mine, Drum Valley, C. Knowlton (p.c.'46).

CASSITERITE

Kern County: 1, Additional reference for Meeke Mine, Page (3) p. 202.

CELESTITE

San Bernardino County: 1, Celestite pseudomorphous after satin-spar, is reported from the Borate locality, D. J. Henry (1) p. 231.

CHLORITE

Penninite

Calaveras County: 1, Rather abundant Kämmererite is found in the chromite ores of the Mayflower property (NW. ¼ sec. 9 T. 1 N., R. 13 E., M.D.), and in minor amounts in neighboring deposits, Cater (2) p. 50.

Tehama County: 1, Kämmererite is found with chromite and uvarovite on North Elder Creek (T. 25 N., R. 7 W., M.D.) Rynearson (3) p. 200.

CHONDRODITE

Riverside County: Deep amber grains of chrondrodite are rather abundant in some of the contact zone limestones of the Jensen Quarry, J. Murdoch (p.c. '47).

CHROMITE

Amador County: Many small deposits of chromite occur throughout the county (T. 5, 6, 7, 8 N., R. 10 E., M.D.), Cater (2) pp. 33-38.

Calaveras County: Details of location of the many chromite deposits, mostly small, in the county (T. 1, 2, 3, 4, 5 N., R. 10, 11, 12, 13 E., M.D.), Cater (2) pp. 33-58.

Mariposa County: 2, Many small chromite deposits are in the region covered by T. 2 S., R. 16 E., M.D., Cater (1) pp. 1-32.

Siskiyou County: Additional reference for numerous small occurrences throughout the county: J. C. O'Brien (4) pp. 419.

Tehama County: Additional reference to occurences throughout the county, J. C. O'Brien (3) p. 186, 187.

Tuolumne County: 2, Additional localities (mostly small), in the county are in the area T. 1, 2, S., 1 N., R. 13, 14, 15 E., M.D., Cater (1) pp. 1-32.

CINNABAR

Inyo County: 2, Additional reference for Coso Hot Springs, C. P. Ross and Yates (6) p. 395.

Monterey County: 1, Cinnabar is reported as occurring in calcite southeast of Jamesburg, (SE. ¼ sec. 31, T. 18 S., R. 5 E., M.D.), W. W. Bradley (p.c. '46).

Santa Clara County: 1, Cinnabar pebbles have been recovered by panning from the gravels of Deep Gulch, close to the New Almaden Mine, E. H. Bailey and Everhart (8) p. 27.

Siskiyou County: 4, Small amounts of cinnabar occur in seams of hornblende schist at the Horse Creek Mercury Mine, (sec. 15, 16, T. 46 N., R. 10 W., M.D.), J. C. O'Brien (4) p. 460.

Sonoma County: Additional and recent report on the Mayacmas district, E. H. Bailey (6) pp. 199-230.

Stanislaus County: Cinnabar occurs in the Del Puerto area, at the Adobe Valley, Summit and Winegar properties, (T. 6 S., R. 5 E., M.D.) Hawkes et al. (2) p. 79.

CLINOZOISITE

Sonoma County: Specimens of clinozoisite S. M. B. (21318), came from 2½ miles east of Valley Ford, associated with glaucophane.

COPIAPITE

Lake County: Additional reference for Sulphur Bank, Everhart (1) p. 139.

COPPER

Tehama County: Small amounts of native copper occurred at Basler, (sec. 4, T. 25 N., R. 7 W., M.D.), J. C. O'Brien (3) p. 189.

COVELLITE

Siskiyou County: 1, Small amounts of covellite occur with some bornite and chalcopyrite at the Preston Peak Mine (sec. 22, T. 17 N., R. 5 E., H.) J. C. O'Brien (4) p. 428.

CRISTOBALITE

Riverside County: 1, Cristobalite has been identified with the lechateliérite, in fulgurites near Indio, A. F. Rogers (50) p. 120. (Confirms A. F. Rogers, p.c. '46.)

CURTISITE

Lake County: 2, Curtisite is reported from the Helen and Research mines, Yates and Hilpert (4) p. 247.

CYRTOLITE

Riverside County: 1, Southern Pacific silica Quarry, near Nuevo, Murdoch (19) p. 198. (Confirms Murdoch p.c. '45.)

DIALLAGE

See pyroxenes.

DIOPSIDE

See pyroxenes.

DUMORTIERITE

Riverside County: 1, Additional reference for Temescal Wash, Larsen (17) p. 106. *3,* Minute blue needles of dumortierite occur in the andalusite pegmatite at the magnesite mine, Winchester, Murdoch (p.c. '46).

EMBOLITE

San Bernardino County: 1, Well formed crystals of embolite have been found in Wall Street Canyon, Calico district, D. J. Henry (1) p. 228.

EPSOMITE

Lake County: 2, Epsomite, associated with copiapite, jarosite and other minerals, is rather common at Sulphur Bank, Everhart (1) p. 136.
Sonoma County: 1, Additional reference for The Geysers, Vonsen (6) p. 290.

GARNET

Calaveras County: 3 (?) Numerous seams of uvarovite in chromite are reported from SW. ¼ sec. 9, T. 1 N., R. 13 E., M.D., Cater (2) p. 50. This may be a confirmation of the unidentified locality reported by Jarvis (p.c. '46).

San Bernardino County: 2, Showy green patches of uvarovite in rock, have been found northeast of Yermo on the road to Coyote Lake, T. V. Little (p.c. '47).

Stanislaus County: 1, Minute crystals of uvarovite, coating fractures and shear planes, are found in the Del Puerto area (T. 6 S., R. 5 E., M.D.), Hawkes et al. (2) p. 91.

Tehama County: 1, Uvarovite is found with chromite and Kämmererite on North Elder Creek (T. 25 N., R. 7 W., M.D.), Rynearson (3) p. 200.

Tuolumne County: 1, A lens of spessartite garnet occurs in a pegmatite one mile north of the town of Tuolumne. Some of the crystals are over 2 inches in diameter, Goudey (2) p. 10.

GEHLENITE

Inyo County: 1, A specimen of gehlenite, S. M. B. (21332), came from the Ubehebe mining district, 2 miles east of Lost Burro Spring.

GEIKIELITE

Magnesium titanate, $MgTiO_3$

Hexagonal rhombohedral. Crystals tabular, sometimes very small. Rhombohedral cleavage. Luster adamantine, color ruby red to nearly black. Transparent red in thin sections. Streak white. H=5-6. G=3.95.

Riverside County: 1, Geikielite occurs in microscopic red grains and crystals disseminated in brucite-limestone, at the Jensen Quarry, Murdoch and Fahey (20) p. 1341. This is the second recorded locality for this exceedingly rare mineral. It had previously been found only in Ceylon.

GLAUCOPHANE

See amphiboles.

HALITE

San Bernardino County: 2, Additional reference for Avawatz Mountains, Phalen (3) p. 526.

HALOTRICHITE

Alpine County: 1, Additional reference to Leviathan mine, Nichols (1), p. 172.

Sonoma County: 1, Halotrichite occurs in small amounts near the Witches Cauldron, The Geysers, Vonsen (6) p. 290 (confirms Vonsen p.c. '45.).

HELVITE

San Diego County: 1, Confirming (Murdoch p.c. '46) for Rincon, Murdoch (18) p. 198.

HEMATITE

Inyo County: 3, Hematite of high grade occurs in the Millspaugh iron deposit, Argus Mountains. (T. 22 S., R. 42 E., M.D.), Tucker (36) p. 319.

San Bernardino County: 5, Additional reference for Kelso, Lamey (5) p. 87. *6,* Massive hematite occurs at the Tiefort Mountains deposit (sec. 22 ?, T. 14 N., R. 4 E., S.B.), Tucker (36) p. 319. *7,* Hematite is found with magnetite in the Old Dad Mountains (sec. 13, 14 ?, T. 12 N., R. 10 E., S.B.), Lamey (3) p. 61. *8,* Hematite and magnetite from the Iron Mountain and Iron King deposits, Silver Lake district (T. 15 N., R. 6, 7 E., S.B.), Lamey (2) p. 39. *9,* Hematite occurs with magnetite in the Iron Hat deposit, (T. 6 N., R. 14 E., S.B.), Lamey (6) p. 99. *10,* Hematite is found in the Ship Mountains deposit (T. 5N., R. 15 E., S.B.), Lamey (7) p. 113.

HEULANDITE

San Diego County: 1, Confirming Rincon (Murdoch p.c. '45), Murdoch (18) p. 198.

HOWLITE

Kern County: 1, Confirming Kramer (H. S. Gale p.c. '46), H. S. Gale (16) p. 332.

IDOCRASE

Placer County: 2, Idocrase has been found in this county, disseminated in massive garnet, A. F. Rogers (51) p. 1222.

ILVAITE

Shasta County: 2, Small amounts of ilvaite have been found in the ore of the Shasta and California Iron ore deposit (sec. 26, T. 34 N., R. 4 W., M.D.), Lamey (9) p. 149.

INDERITE

Hydrous magnesium borate $Mg_2B_6O_{11}.15H_2O$.

Triclinic. Fine prismatic needles and nodules. Luster somewhat greasy, but on cleavage faces pearly. One perfect cleavage and another good. $H = 3$. $G = 1.86$.

Easily soluble in warm HCl. Readily fusible to a white bead. Gives off slightly alkaline water in closed tube.

Kern County: 1, A few grains of inderite were identified by Dr. Clifford Frondel, in a specimen from a drill core from the Baker mine at Boron, in the Kramer district, Mineral Notes and News (3) p. 12. This is the first Californian, and second American, occurrence of this mineral, which was found elsewhere only in the Inder region of West Kazakstan.

JAROSITE

Lake County: 1, Jarosite occurs associated with copiapite and epsomite at Sulphur Bank, Everhart (1) p. 139.

KÄMMERERITE

See chlorite.

KERMESITE

Kern County: Kermesite was reported from the Kramer district, as small cherry red spherules with kramerite, Mineral Notes and News (4) p. 13. According to Frondel (p.c. '48) this is not Kermesite, but an unidentified and possibly new mineral.

LAWSONITE

Sonoma County: 4, A specimen, S.M.B. (21317) from $2\frac{1}{2}$ miles northeast of Valley Ford, confirms Vonsen (p.c. '45).

LECHATELIÉRITE

Riverside County: 1, Confirming (A. F. Rogers p.c. '46), A. F. Rogers (50) p. 120.

LUDWIGITE

Kern County: 1, Additional reference for Meeke mine, Page (3) p. 202.

MAGNETITE

San Bernardino County: 3, Additional reference for Providence Mountains, Lamey (5) p. 87. *4,* Magnetite and hematite occur in the Ship Mountain deposits (T. 5 N., R. 15 E., S.B.), Lamey (7) p. 113. *5,* Magnetite is found with hematite at the Iron Hat (T. 6 N., R. 14 E., S.B.) Lamey

(6) p. 99. *6,* Hematite and magnetite occur in the Old Dad Mountain deposit (sec. 13, 14 ?, T. 12 N., R. 10 E., S.B.), Lamey (3) p. 61. *7,* Magnetite is found with hematite in the Silver Lake district, Iron Mountain deposits (T. 15 N., R. 6, 7, E., S.B.) Lamey (2) p. 39.

Shasta County: 1, A small deposit of magnetite, with garnet and epidote, occurs at the Hirz Mountains deposit (T. 35 N., R. 3 W., M.D.), Lamey (8) p. 131.

MANGANITE

Imperial County: 1, Minor amounts of manganite are found with pyrolusite and psilomelane in the Paymaster district (sec. 16, 18, 19, T. 11 S., R. 21 E., S.B.), Tucker (11) p. 266, Hadley (1) p. 465.

MARCASITE

Lake County: 4, Considerable marcasite was found in some of the ores of the Helen mine (sec. 1, T. 10 N., R. 8 W., M.D.), Tucker (36) p. 276.

MASCAGNITE

Sonoma County: 1, Additional reference to The Geysers, Vonsen (6) p. 288. The mineral occurs as incrustations and nodules during the early summer months, in the upper part of Geyser Creek Canyon.

MELANTERITE

Alpine County: 1, Additional reference to Leviathan mine, Nichols (1) p. 172.

Sonoma County: 3, Melanterite has been observed as occurring sparingly at The Geysers, Vonsen (6) p. 291.

MILLERITE

Lake County: 1, Millerite occurs in the Great Western mine, in very small amount, Yates and Hilpert (4) p. 246.

Napa County: 6, Millerite is found in the Twin Peaks mine, Yates and Hilpert (4) p. 246.

MOLYBDENITE

Riverside County: 1, Molybdenite occurs with other sulphides in shear zones of quartz, at the southeast base of Mount Hale (sec. 10 ?, T. 3 S., R. 6 W., S.B.), Larsen (17) p. 96.

MONAZITE

Riverside County: 4, It seems probable that the monazite crystals reported west of the Jensen Quarry, are sphene instead, as this mineral is abundant there, Murdoch (p.c. '47). *6,* Monazite has been reported from fine-grained granite, on the west side of Mt. Rubideaux, Larsen (p.c. '46). *7,* Monazite has been reported as a minor constituent of tonalite, together with anatase and zircon, from a tunnel south of Val Verde, R. W. Wilson (1) p. 124.

NAPALITE

Napa County: 3, Napalite is reported from the Aetna mine, Yates and Hilpert (4) p. 247.

* NUEVITE, 1946

A mineral of the samarskite group, niobate of titanium and iron, with yttrium and uranium.

Riverside County: 1, An aggregate of poorly formed crystals and grains of nuevite were found associated with crytolite in quartz and feldspar, at the Southern Pacific Silica Quarry near Nuevo. Named for the locality, Murdoch (19) p. 1219.

OLIVINE

Shasta County: 1, Massive coarse grained peridotite showing very good cleavage on the olivine grains, has been observed near the Little Creek chromite mine, Hawkes (3) p. 277.

OPAL

Sonoma County: 3, Confirms reference for The Geysers, Vonsen (p.c. '45), Vonsen (6) p. 291.

PETALITE

San Diego County: 1, Confirms reference for Rincon, Murdoch (p.c. '45), Murdoch (18) p. 198.

PHILLIPSITE

Kern County: 1, Occasional cavities in basalt at Red Rock Canyon have been found to contain pale salmon pink phillipsite in poor crystals, J. Murdoch (p.c. '47).

PHLOGOPITE

Riverside County: 2, Abundant crystals of phlogopite, up to one inch in diameter have been found in the contact zone at the Jensen Quarry, J. Murdoch (p.c. '47).

PHOSPHOSIDERITE

Iron phosphate, $2(FePO_4)3\frac{1}{2}H_2O$.

Orthorhombic. Crystals prismatic. Often in minute spherules. One perfect cleavage. H=3-4. G= 2.76. Soluble in HCl. Fuses easily to a black bead.

San Diego County: 1, What is presumably the same violet-colored material from Pala which was called strengite by Schaller (29) p. 145, has been identified by x-ray study as phosphosiderite, C. Frondel (p.c. '48). It is associated with yellow stewartite, and oxides of manganese.

PITTICITE

Tuolumne County: 1, Brown colloidal material from the Carlin mine near Jamestown, has been referred to this species, Goudey (3) p. 12.

PROBERTITE

Kern County: 2, Additional references for Kramer district, Murdoch (17) p. 720, H. S. Gale (16) p. 362, both for the Suckow mine. The earlier reference was to an occurrence in the West Coast Borax Co.'s mine.

---

* Species first discovered in California are marked by an asterisk and followed by date of first published description.

PSILOMELANE

Imperial County: 4, Psilomelane is found in the Paymaster district (sec. 16, 18, 19, T. 11 S., R. 21 E., S.B.) Hadley (1) p. 465.

PUMPELLYITE

San Mateo County: 1, Pumpellyite has been reported in quartzo-feldspathic rocks, Hutton (1) p. 1373.

PYROLUSITE

Imperial County: 1, Additional reference to Tolbard, Hadley (1) p. 465.

PYROMORPHITE

Inyo County: 2, Euhedral crystals of pyromorphite have been found in the Darwin Mines, in oxidized lead ore, C. D. Woodhouse (p.c.'47).

PYROPHYLLITE

Inyo County: 2, Pyrophyllite has been shipped from a deposit 17 miles north of Laws, Mineral Information Service, Calif. Div. Mines #2, April 7, 1947.

San Diego County: 2, Reference confirming Escondido locality, D. F. Palmer (1) p. 5.

PYROXENES

Diallage

Contra Costa County: 1, Gabbro containing a high proportion of pure diallage, occurs on Bagley Creek about 1½ miles due north of Mt. Diablo peak, H. W. Turner (1) p. 391.

Diopside

Riverside County: 2, Large green crystals of diopside appear in the contact zone at the New City quarry, south of Riverside, Larsen (17) p. 34. *3,* Coarse-grained diopside with garnet occurs at a limestone-gabbro contact 1½ miles northeast of Winchester, ibid., p. 35.

Quartz

San Bernardino County: 6, Quartz pseudomorphs after natrolite, from 3 miles north of Calico, are represented by S.M.B. (21313).

REALGAR

Los Angeles County: 1, Very thin films and crystals of realgar appear on fracture surfaces in massive colemanite from the Sterling Borax mine, Tick Canyon, H. Stager (p.c.'47).

RHODONITE

Tulare County: 2, Occasional layers of rhodonite, formed by metamorphism of manganiferous cherts, are found near Greasy Creek and on the west side of Dry Creek, Durrell (2) p. 32.

RIEBECKITE

See amphiboles.

RÖMERITE

Alpine County: 1, Additional reference to Leviathan mine, Nichols (1) p. 172.

RUTILE

San Bernardino County: 1, Discontinuous concentrations of rutile occur in thin beds of quartzite near the Mojave river southwest of Barstow (SE¼ SW¼ sec. 21, T. 9 N., R. 3 W., S.B.), W. H. Grant (p.c. '47).

SCAPOLITE

Inyo County: 2, A specimen, S.M.B. (21326) of scapolite, with chrysocolla has been received from 3 miles east of Dodd Spring, Ubehebe mining district.

SCHEELITE

Since the preparation of Bulletin 136, there has been much intensive prospecting for tungsten, and a great many new localities have been found. In general, they are not of very great commercial importance, but they will be listed here for the record. All of these references are to occurrences not covered by the previous bulletin.

Fresno County: 1, One mile southwest of Dunlap (sec. 3, T. 14 S., R. 26 E., M.D.), Kerr (6) p. 139.

Inyo County: 3, Copper Queen, 4 miles south of Oasis (sec. 7, T. 6 S., R. 37 E., M. D.), Kerr (6) p. 141. *4,* Northeast flank of the Inyo Mountains (sec. 19, T. 8 S., R. 37 E., M.D.) ibid. p. 141, *5,* Trail Canyon, Sheephead claim (T. 19 S., R. 46 E., M.D.) ibid. p. 147.

Kern County: 2, Gorman district, with cassiterite, ludwigite, etc., Page (3) p. 202. *3,* Cottonwood Canyon (T. 30 S., R. 35 E., M.D.) Kerr (6) p. 151. *4,* Indian Creek, 12 miles east of Caliente (T. 30 S., R. 33 E., M.D.), ibid. p. 151.

Madera County: 1, Many occurrences in the Jackass Creek area (T. 4 S., R. 24, 25 E., M.D.) Kerr (6) p. 157. *2,* North fork, San Joaquin River (T. 8 S., R. 23, 24 E., M.D.), ibid. p. 156. *3,* Yellowjacket (sec. 3, 4, 10, T. 5 S., R. 23 E., M.D.) ibid. p. 157.

Mono County: 1, In tactite north of Tioga Pass (sec. 6, T. 2 N., R. 25 E., M.D.) Kerr (6) p. 160. *2,* Topaz Lake district (T. 7, 8, 9 N., R. 22, 23 E., M.D.) ibid. p. 160.

Riverside County: 1, Alice Group (sec. 25, 36, T. 1 S., R. 23 E., S. B.), Kerr (6) p. 162. *2,* Six miles southwest of Perris, ibid. p. 161. *3,* Beatty claims, six miles west of Perris (sec. 32, 33, 34, T. 4 S., R. 4 W., S. B.), ibid. p. 161.

San Diego County: 1, In aplite dikes in Mason Valley, sixty miles east of San Diego, close to the Mexican border, Kerr (6) p. 165. *2,* In tactite, in the Laguna Mountains (sec. 28, T. 15 S., R. 4 E., S. B.) ibid. p. 165.

Trinity County: 1, Stewart Fork, 10 miles northwest of Minersville (sec. 10, T. 35 N., R. 9 W., M.D.) Kerr (6) p. 166.

Tulare County: 1, Mineral King, Near Empire mine (sec. 11, 16, T. 17 S., R. 31 E., M.D.) Kerr (6) p. 167. *2,* Near Middle Fork, Kaweah River (sec. 13, T. 16 S., R. 29 E., M.D.), ibid. p. 167. *3,* Brush Creek near Fairview (sec. 36, T. 22 S. R. 32 E., M.D.) ibid. p. 168. *4,* Tule Indian Reservation (sec. 7, T. 22 S., R. 30 E., M.D.), ibid. p. 168.

Tuolumne County: Dorothy Lake, Yosemite National Park (sec. 20, T. 4 N., R. 22 E., M.D.) Kerr (6) p. 168.

Yuba County: Stephens, Dobbins Ranch (sec. 7, T. 17 N., R. 7 E., M.D.), Kerr (6) p. 169.

SCORODITE

Tuolumne County: 1, Scorodite has been reported as druses and crusts of gray green crystals of octahedral habit, Goudey (3) p. 12.

SILLIMANITE

San Diego County: 3, Abundant and wide spread occurrences of sillimanite as needles in quartz-muscovite-sillimanite schist are found south and east of Ramona (T. 12 S., R. 2 E., S.B.), confirming R. Merriam (p.c. '46) Merriam (4) p. 228. *4,* In the Mesa Grande area needles up to 1 to 2 centimeters occur in the schists, confirming R. Merriam (p.c. '46) ibid. p. 228. *5,* Sillimanite occurs in gneiss at the entrance to Palm Canyon, Borego Valley, C. Durrell (p.c. '48) *6,* Sillimanite is abundant in blocks of breccia in Split Mountain canyon, C. Durrell (p.c. '48).

SPESSARTITE

See garnet.

SPHENE

Inyo County: 3, Sphene occurs rather abundantly in large well-formed crystals (up to 2 inches in length), at the foot of the Palisade Glacier, D. I. Axelrod, (p.c. '46).

Imperial County (?): Chromiferous sphene from the "southern California desert area," was examined by Jaffe (1) p. 640.

SPINEL

Inyo County: Spinel, variety pleonaste, has been found in the south end of Butte Valley, Ubehebe (?) mining district, S.M.B. (21329).

SPODUMENE

San Diego County: 2, Confirming Rincon occurrence Murdoch (p.c. '45), Murdoch (18) p. 198.

STELLERITE

See stilbite.

STIBNITE

Lake County: Additional reference to Sulphur Bank, Everhart (1) p. 139.

STILBITE

San Diego County: 4, "Stellerite" has been recorded as abundant in irregular veins in a quartz latite stock at the head of the south fork of San Onofre Creek, Larsen (17) p. 111. *5,* Stilbite is found in veins in granodiorite boulders in Fish Creek wash, 2-3 miles south of the Fish Creek Mountains gypsum deposit, J. Murdoch (p.c. '48).

Sonoma County: 1, Confirming Vonsen (p.c. '45) for the occurrence of small tabular crystals of "stellerite" at The Geysers, Vonsen (6) p. 292.

STILPNOMELANE

Santa Clara County: 1, Stilpnomelane has been reported in some of the glaucophane schists of the New Almaden region, Hutton (1) p. 1373.

SZAIBELYITE

Hydrous magnesium borate, $2MgO.B_2O_3.H_2O$.
Orthorhombic. Fibrous. White. H less than 3. G.2.6
Readily fusible. Soluble in acids.

Marin County: 1, Szaibelyite occurs as impregnations and coatings on serpentine near Stinson Beach. It was first observed and analyzed by Eakle (24) p. 100, who considered it to be camsellite. Schaller (44) p. 230, suggested the identity of camsellite and szaibelyite, and Watanabe (1) p. 454, has reported the identity of camsellite from California, with szaibelyite from Leopoldshall, Germany. Schaller (53) p. 470, has shown definitely that szaibelyite = (ascharite, camellite, β-ascharite).

TIEMANNITE

Lake County: 2, Tiemannite is reported in the ore of the Helen mine (sec. 1, T. 10 N., R. 8 W., M.D.), Yates and Hilpert (4) p. 278.

TILLEYITE

Analysis of excellent material from Ireland, Nockolds (1) p. 151, indicates that the formula should be $2\ CaCO_3.\ Ca_3Si_2O_7$.

TINCALCONITE

San Bernardino County: 1, Well formed crystals of tincalconite up to 4 mm. across have been found in drill cores at Searles Lake. It is associated with trona and borax, Pabst and Sawyer (10) p. 472.

TRIDYMITE

San Diego County: 1, Tridymite constitutes up to 25 percent of a dacite volcanic neck at Morro Hill, 6 miles south of Fallbrook (sec. 23, T. 10 S., R. 4 W., S.B.), Larsen (17) p. 111.

TSCHERMIGITE

Sonoma County: 1, Many brilliant octahedral crystals of tschermigite, and also crusts and crystalline masses, occur in Upper Geyser Canyon and Lemonade Spring, The Geysers, additional reference Vonsen (6) p. 289.

UVAROVITE

See garnet.

VIOLARITE

San Diego County: 1, Additional reference to occurrence in the Friday mine, Creasey (1) p. 27.

VIVIANITE

Inyo County: 1, Vivianite in crystals on quartz is reported from the Darwin mines, C. D. Woodhouse (p.c. '47).

VOLTAITE

Sonoma County: 1, Additional reference—voltaite occurs as black crusts in Geyser Creek Canyon, near the Witches Cauldron, Vonsen (6) p. 291.

WOLLASTONITE

Riverside County: The triclinic character of some wollastonite was confirmed on excellent crystals from Crestmore, Peacock (3) p. 495. *4,* Wollastonite occurs with scapolite in the iron ores at Eagle Mountain, Hadley (1) p. 4.

San Diego County: 2, A specimen, S.M.B. (21224) confirms the record for the occurrence of wollastonite in Carrizo Gorge, Symons (5) p. 62.

XANTHOPHYLLITE

Riverside County: 2, Xanthophyllite occurs in minor amounts in a contact zone 1½ miles northeast of Winchester, Larsen (17) p. 36.

ZIRCON

Los Angeles County: 1, Abundant clear pinkish crystals of zircon have been found in a pegmatite in Pacoima Canyon (NE¼ sec. 6, T. 3 N., R. 13 W., S. B.), G. Neuerburg (p.c. '47).

ZOISITE

Mono County: 1, Zoisite, variety *thulite* has been found near Baldwin Mountain, associated with scheelite in a contact zone, Kerr (6), p. 159.

BIBLIOGRAPHY

Serials Consulted

Acad. Nat. Sci. Philadelphia. Academy of Natural Sciences of Philadelphia.
Proceedings.
Notulae Naturae.

Am. Acad. Arts Sci. American Academy of Arts and Sciences, Boston.
Proceedings.

Am. Assoc. Advancement Sci. American Association for the Advancement of Science, New York.
Proceedings.

Am. Assoc. Petroleum Geologists. American Association of Petroleum Geologists.
Bulletin.

Am. Jour. Sci. American Journal of Science, New Haven.

Am. Mineralogist. American Mineralogist, Lancaster, Penn.

Am. Mus. Nat. Hist. American Museum of Natural History, New York.
Bulletin.
Memoirs.
Novitiates.

California Acad. Sci. California Academy of Sciences, San Francisco.
Proceedings.

California Div. Mines. California State Division of Mines.
Reports-Journals.
Bulletins.
Mineral Information Service.

Carnegie Inst. Washington. Carnegie Institution of Washington.
Publications.

Econ. Geology. Economic Geology, Lancaster, Penn.

Eng. and Min. Jour. Engineering and Mining Journal, New York.

Gems and Gemology
1934+

Geol. Soc. America. Geological Society of America.
Bulletin.
Memoirs.

Geol. Soc. London. Geological Society of London.
Quarterly Journal.

Mineral Notes and News, Bakersfield, California.

Mineralog. Mag. Mineralogical Magazine and Journal of the Mineralogical Society, London.

Mineralog. Mitt. Mineralogische und petrographische Mitteilungen, Vienna.

Mineralogist, The. Portland, Oregon.

Mining and Metallurgy. American Institute of Mining and Metallurgical Engineers, New York.

Nature, London.

Rocks and Minerals, Peekskill, New York.

San Diego Department of Agriculture. Division of Natural Resources, San Diego, Calif.
Annual Reports 1945+

Science, Cambridge, Mass., New York.

Smithsonian Institution
Annual Reports.
Miscellaneous Papers.

Soc. Franc. Mineralogic. Société française de Minéralogie, Paris.
Bulletins.

U. S. Bur. Mines. United States Bureau of Mines, Washington.
Bulletins.
Technical Papers.
Information Circulars.
Minerals Yearbook.

U. S. Geol. Survey. United States Geological Survey, Washington.
Professional Papers.
Bulletins.
Water-Supply Papers.

References

Allen, John E.

3. Geology of the San Juan Bautista quadrangle, California: California Div. Mines Bull. 133, 75 pp., 1946 . . . (abstract) Geol. Soc. America Bull. 56, p. 1143, 1945.

Allen, Victor T.

6. Sedimentary and volcanic processes in the formation of high alumina clays: Econ. Geology, vol. 41, pp. 124-138, 1946.

7. Some United States boehmite localities: (abstract) Geol. Soc. America Bull. 57, p. 1173, 1946.

Averill, Charles V.

14. Mines and mineral resources of Lake County, California: California Div. Mines Rept. 43, pp. 15-40, 1947.

15. Mines and mineral resources of San Benito County, California: California Div. Mines Rept. 43, pp. 41-60, 1947.

16. (**King, C. R., Symons, H. H., and Davis, F. F.**) California mineral production for 1946: California Div. Mines Bull. 139, 76 pp. 1948.

Bailey, Edgar H.

5. Quicksilver deposits of the Parkfield district, California: U. S. Geol. Survey Bull. 936 F., pp. 143-169, 1942.

6. Quicksilver deposits of the western Mayacmas district, Sonoma County, California: California Div. Mines Rept. 42, pp. 199-230, 1946.

7. (and **Swinney, C. M.**) Walibu quicksilver mine, Kern County, California; California Div. Mines Rept. 43, pp. 9-14, 1947.

8. (and **Everhart, D. L.**) Almaden placer yields cinnabar-rich gravels; Eng. Min. Jour., vol. 148, pp. 77-79, 1947.

Berry, L. G.

1. See Whitmore, D. R. E. 1.

Bradley, Walter W.

35. Observations at "The Geysers," Sonoma County, California: California Div. Mines Rept. 42, pp. 295-298, 1946.

Bramlette, Milton N.

3. See Woodring, W. P. 1.
4. The Monterey formation of California and the origin of its silicious rocks: U. S. Geol. Survey Prof. Paper 212, 57 pp., 1946.

Cater, F. W. Jr.

1. Chromite deposits of Tuolumne and Mariposa Counties, California: California Div. Mines Bull. 134, pt. III, Chap. 1, pp. 1-32, 1948.
2. Chromite deposits of Calaveras and Amador Counties, California: California Div. Mines Bull. 134, pt. III, Chap. 2, pp. 33-58, 1948.

Charles, Abbott

1. Mines and minerals of Stanislaus County: California Division Mines Rept. 43, pp. 85-100, 1947.

Daviess, S. N.

1. Mineralogy of late Upper Cretaceous, Paleocene and Eocene sandstones of Los Banos district, west border of San Joaquin Valley, California: Am. Assoc. Petroleum Geologists Bull. 30, pp. 63-83, 1946.

Davis, F. F.

1. Mines and mineral resources of Napa County, California: California Div. Mines Rept. 44, pp. 159-188, 1948.
2. See Averill, C. V., 16.

Dow, D. H.

1. (and **Thayer, T. P.**) Chromite deposits of the northern Coast Ranges of California: California Div. Mines Bull. 134, pt. 2, pp. 1-38, 1946.

Durrell, Cordell

5. Strontium deposits of southern California (abstract): Geol. Soc. America Bull. 58, p. 1250, 1947.
6. (and **Procter, P. D.**) Iron ore deposits near Lake Hawley and Spencer Lakes, Sierra County, California: California Div. Mines Bull. 129, pp. 165-192, 1948.

Eckel, E. B.

2. (and **Myers, W. B.**) Quicksilver deposits of the New Idria district, San Benito and Fresno Counties, California: California Div. Mines Rept. 42, pp. 81-124, 1946.

Engineering and Mining Journal

31. Salute to the Golden State: vol. 149, no. 1, pp. 52-55, 1948.

Everhart, D. L.

1. Quicksilver deposits at the Sulphur Bank mine, Lake County, California: California Div. Mines Rept. 42, pp. 125-153, 1946.
2. See Bailey, E. H. 8.
3. See Myers, W. B. 3.

Fahey, J. J.

1. See Murdoch, J. 20.

Gale, H. S.

16. Geology of the Kramer borate district, Kern County, California: California Div. Mines Rept. 42, pp. 325-378, 1946.

Goldschmidt, V.

1. (**Palache, C.** and **Peacock, M. A.**) Über Calaverit: Neues Jahrb. f. Min. etc. B.B. 63, Abt. A., pp. 1-58, 1931.

Goudey, H.

2. Spessartite near Tuolumne, California: Mineral Notes and News Bull. 114, p. 10, March 1947.

3. Scorodite near Jamestown, California: Mineral Notes and News, Bull. 114, p. 12, March 1947.

Hadley, J. B.

1. Manganese deposits in the Paymaster mining district, Imperial County, California: U. S. Geol. Survey Bull. 931 S, pp. 459-473, 1942.

2. Iron-ore deposits in the eastern part of the Eagle Mountains, Riverside County, California: California Div. Mines Bull. 129, pp. 1-24, 1948.

Hawkes, H. E.

2. (**Wells, F. G.** and **Wheeler, D. P. Jr.**) Chromite and quicksilver deposits of the Del Puerto area, Stanislaus County, California: U. S. Geol. Survey Bull. 936 D, pp. 79-110, 1942.

3. Olivine from northern California showing perfect cleavage: Am. Mineralogist vol. 31, pp. 276-283, 1946.

Hawley J. E.

1. See Whitmore, D. R. E. 1.

Henley, R. F.

1. Jade in California: Rocks and Minerals, vol. 22, pp. 1114-1115, 1947.

Henry, D. J.

1. The California Calico Mountains: The Mineralogist, vol. 14, pp. 225-233, 1946.

2. The northeast portion of Eagle Crags: The Mineralogist, vol. 14, pp. 339-342, 1946.

3. Collecting Kern County, California: The Mineralogist, vol. 15, pp. 3-7, 1947.

4. Wiley Well district a mecca for the collector: The Mineralogist, vol. 15, pp. 171-176, 1947.

5. Black Hills, California: The Mineralogist, vol. 15, pp. 451-453, 1947.

Hewett, D. F.

2. Iron deposits of the Kingston Range, San Bernardino County, California: California Div. Mines Bull. 129, pp. 193-206, 1948.

Heyl, G. R.

1. Foothill copper-zinc belt of the Sierra Nevada (abstract): Geol. Soc. America Bull. 58, p. 1253, 1947.

Hilpert, L. S.

2. See Yates, R. G. 4.

Huey, A. S.

1. Geology of the Tesla quadrangle, California: California Div. Mines Bull. 140, 75 pp., 1948.

Hutton, C. O.

1. Stilpnomelane and pumpellyite, constituents of the Franciscan series (abstract): Geol. Soc. America Bull. 59, pp. 1373-1374, 1948.

Jaffe, H. W.

1. Re-examination of sphene: Am. Mineralogist, vol. 32, pp. 637-642, 1947.

Jahns, R. H.

1. Internal structure of the Pala pegmatites, San Diego County, California (abstract): Geol. Soc. America Bull. 58, p. 1254, 1947.

2. Gem deposits of southern California: Gems and Gemology, vol. 6, pp. 6-9, 28, 30, 1948.

Jenkins, O. P.

3. Annual report of the State Mineralogist: California Div. Mines Rept. 45, pp. 7-29, 1949.

Kerr, P. F.

6. Tungsten mineralization in the United States: Geol. Soc. America Mem. 15, 241 pp., 1946.

Kew, W. S.

1. See Woodring, W. P. 1.

King, C. R.

1. See Averill, C. V. 16

Lamey, C. A.

1. Iron Mountain iron-ore deposits, Lava Beds district, San Bernardino County, California: California Div. Mines Bull. 129, pp. 25-38, 1948.
2. Iron Mountain and Iron King iron-ore deposits, Silver Lake District, San Bernardino County, California: California Div. Mines Bull. 129, pp. 39-58, 1948.
3. Old Dad Mountain iron-ore deposit, San Bernardino County, California: California Div. Mines Bull. 129, pp. 59-68, 1948.
4. Cave Canyon iron-ore deposits, San Bernardino County, California: California Div. Mines Bull. 129, pp. 69-84, 1948.
5. Vulcan iron-ore deposit, San Bernardino County, California: California Div. Mines Bull. 129, pp. 85-96, 1948.
6. Iron Hat (Iron-Clad) iron-ore deposits, San Bernardino County, California: California Div. Mines Bull. 129, pp. 97-110, 1948.
7. Ship Mountains iron-ore deposit, San Bernardino County, California: California Div. Mines Bull. 129, pp. 113-116, 1948.
8. Hirz Mountain iron-ore deposits, Shasta County, California: California Div. Mines Bull. 129, pp. 129-136, 1948.
9. Shasta and California iron-ore deposits, Shasta County, California: California Div. Mines Bull. 129, pp. 137-164, 1948.

Larsen, E. S.

17. Batholith and associated rocks of Corona, Elsinore, and San Luis Rey quadrangles, southern California: Geol. Soc. America Mem. 29, 182 pp., 1948.

Lisle, T. O.

1. Amethysts of the Bullfrog mine and Death Valley onyx: Rocks and Minerals, vol. 21, pp. 200-204, 1946.

Logan, C. A.

22. Limestone in California: California Div. Mines Rept. 43, pp. 177-357, 1947.

Mathewson, H. D.

1. A day at the Mirabel and Sulphur Bank mines: Rocks and Minerals, vol. 23, pp. 312-315, 1948.

Merriam, Richard

4. Igneous and metamorphic rocks of the southwestern part of the Ramona quadrangle, San Diego County, California: Geol. Soc. America Bull. 57, pp. 223-260, 1946.

Miller, William J.

9. Crystalline rocks of southern California: Geol. Soc. America Bull. 57, pp. 457-542, 1946.

Mineral Notes and News

1. Underwood discovers new benitoite deposit: Mineral Notes and News, Bull. 96, p. 3, 1945.
2. Ramona yields fine specimens: Mineral Notes and News, Bull. 104, p. 7, 1946.
3. Inderite discovered at Boron: Mineral Notes and News, Bull. 127, p. 12, 1948.
4. Kermesite at Boron: Mineral Notes and News, Bull. 127, p. 13, 1948.

Murdoch, Joseph

18. Progress on revision of Bulletin 113 "Minerals of California," with notes on some new mineral occurrences: California Div. Mines Rept. 42, pp. 197-198, 1946. . . . (abstract): Geol. Soc. America Bull. 57, p. 1256, 1946.
19. Nuevite, a new rare-earth mineral from California (abstract): Geol. Soc America Bull. 57, p. 1219, 1946.
20. (and **Fahey, J. J.**) Geikielite, a new find from California (abstract): Geol. Soc. America Bull. 59, pp. 1341-1342, 1948.

Myers, T. R.

1. Green lazulite from Stoddard, New Hampshire: Am. Mineralogist, vol. 33, pp. 366-368, 1948.

Myers, W. B.

2. See Eckel, E. B. 2.
3. (and **Everhart, D. L.**) Quicksilver deposits of the Guerneville district, Sonoma County, California: California Div. Mines Rept. 44, pp. 255-277, 1948.

Nichols, J. B.

1. Collecting minerals in Alpine County, California: The Mineralogist, vol. 14, pp. 171-175, 1946.

Nockolds, S. R.

1. On tilleyite and its associated minerals from Carlingford, Ireland: Mineralog. Mag. vol. 28, pp. 151-158, 1947.

Oakeshott, G. B.

2. Titaniferous iron-ore deposits of the western San Gabriel Mountains, Los Angeles County, California: California Div. Mines Bull. 129, pp. 243-266, 1948.

O'Brien, J. C.

3. Mines and mining in Tehama County, California: California Div. Mines Rept. 42, pp. 183-195, 1946.
4. Mines and mineral resources of Siskiyou County: California Div. Mines Rept. 43, pp. 413-468, 1947.
5. Current and recent mining activities in the Redding district: California Div. Mines Rept. 44, pp. 336-378, 1948.

Pabst, Adolf

9. Some computations on svanbergite, woodhouseite and alunite: Am. Mineralogist vol. 31, pp. 16-30, 1947.
10. (and **Sawyer, D. L.**) Tincalconite crystals from Searles Lake, San Bernardino County, California: Am. Mineralogist, vol. 33, pp. 472-481, 1948.

Page, L. R.

3. Contact metamorphic deposits of cassiterite in California (abstract): Geol. Soc. America Bull. 56, p. 1187, 1945. . . . (abstract): Am. Mineralogist vol. 31, p. 202, 1946.

Palache, Charles

11. See Goldschmidt, V. 1

Palmer, D. F.

1. Second Ann. Rept. San Diego County Department of Agriculture, Division of Natural Resources, vol. 2, no. 2, 1946.

Peacock, M. A.

2. See Goldschmidt, V. 1
3. On wollastonite and parawollastonite: Am. Jour. Sci. 5th ser., vol. 30, pp. 495-529, 1935.

Proctor, P. D.

1. See Durrell, C. 6

Rogers, Austin F.

50. Sand fulgurites with enclosed lechateliérite from Riverside County, California: Jour. Geology vol. 54, pp. 117-122, 1946 . . . (abstract): Am. Mineralogist vol. 31, p. 206, 1946.
51. Garnet-idocrase rock, a pseudo-jade from Placer County, California (abstract): Geol. Soc. America Bull. 58, p. 1222, 1947.
52. Blue agate of Lead Pipe Springs, San Bernardino County, California (abstract): Geol. Soc. America Bull. 58, p. 1256, 1947.

Ross, C. P.

6. (and **Yates, R. G.**) The Coso quicksilver district, Inyo County, California: U.S. Geol. Survey Bull. 936 Q, pp. 395-416, 1943.

Rynearson, G. A.

3. Chromite deposits of the North Elder Creek area, Tehama County, California: U.S. Geol. Survey Bull. 945 G, pp. 191-210, 1946.

Sawyer, D. L.

1. See Pabst, A. 10.

Simons, F. S.

2. See Trask, P. D. 5

Swinney, C. M.

1. See Bailey, E. H. 7.

Symons, H. H.

5. Accessions to the exhibit: California Div. Mines Rept. 42, pp. 61-62, 1946.
6. See Averill, C. V. 16.

Thayer, T. P.

1. Preliminary chemical correlation of chromite with the containing rocks: Econ. Geology, vol. 41, pp. 202-217, 1946.
2. See Dow, D. H. 1.

Trainer, J. S.

1. Green garnets: uvarovite: Rocks and Minerals, vol. 21, pp. 652-654, 1946.
2. Eight recent garnet finds: Rocks and Minerals, vol. 22, pp. 811-818, 1947.
3. Vicinal forms on garnets: Rocks and Minerals, vol. 23, pp. 105-107, 1948.

Trask, Parker D.

5. (and **Simons, F. S.**) Minarets magnetite deposits of Iron Mountain, Madera County, California: California Div. Mines Bull. 129, pp. 117-128, 1948.

Tucker, W. B.

36. Current notes—Inyo County, San Bernardino County: California Div. Mines Rept. 42, p. 319, 1946.

Vonsen, M.

6. Minerals at "The Geysers," Sonoma County, California: California Div. Mines Rept. 42, pp. 287-293, 1946.

Watanabe, T.

1. Kotoit, ein neues gesteinsbildenes magnesiumborat: Min. u. Petr. Mitth. vol. 50, pp. 441-463, 1939.

Wells, F. G.

3. See Hawkes, H. E. 2.

Whitmore, D. R. E.

1. (**Berry, L. G.**, and **Hawley, J. E.**) Chrome micas: Am. Mineralogist, vol. 31, pp. 1-23, 1946.

Wheeler, D. P. Jr.

2. See Hawkes, H. E. 2.

Wilson, R. W.

1. Heavy accessory minerals of the Val Verde tonalite: Am. Mineralogist, vol. 22, pp. 122-132, 1937.

Woodring, W. P.

1. (**Bramlette, M. N.**, and **Kew, W. S. W.**) Geology and paleontology of Palos Verdes Hills, California: U.S. Geol. Survey Prof. Paper 207, 125 pp., 1946.

Yates, R. G.

3. See Ross, C. P. 6
4. (and **Hilpert, L. S.**) Quicksilver deposits of eastern Mayacmas district, Lake and Napa Counties, California: California Div. Mines Rept. 42, pp. 231-286, 1946.

WATER-FLOODING AS A METHOD OF INCREASING CALIFORNIA OIL PRODUCTION *

By Wilbur H. Somerton **

OUTLINE OF REPORT

Page
Part 3, Current and proposed water-flooding research in California ____ 541
Past research ____ 542
Current research activities ____ 544
Problems in the application of water-flooding in California ____ 547
Legal problems ____ 547
Physical problems ____ 547
Conclusions and recommendations ____ 550
Acknowledgments ____ 551

PART 3—CURRENT AND PROPOSED WATER-FLOODING RESEARCH IN CALIFORNIA

The need for secondary recovery research is perhaps so obvious as to require no further amplification. This need has been repeatedly emphasized in the first two parts of this paper and is further emphasized in the literature. Muskat, in reviewing research in the closely allied field of reservoir engineering, states that ''what we already know about oil reservoirs constitutes little more than a good beginning in exploring a vast and difficult field of science.''[1] As far as secondary recovery research in California is concerned, we have not even achieved a good beginning. Scott,[2] in reviewing the 14 years of progress in water-flooding research at Pennsylvania State College points out that although considerable progress has been made, there remains much to be learned about the physical and chemical characteristics of the oil reservoir. Hughes,[3] Andrus,[4] Van Wingen and Johnston [5] and many others have reviewed past progress of secondary recovery research. Pointing to the need for considerable future research, they have listed a great number of pertinent topics. To this list must be added many special research problems of particular significance to California conditions.

---

* Part 3, *Current and Proposed Water-Flooding Research in California,* is the last of three articles by Mr. Somerton on *Water-Flooding as a Method of Increasing California Oil Production.* Part 1, *Factors Influencing the Application of Water-Flooding,* was published in the California Journal of Mines and Geology, vol. 45, no. 2, for April 1949. Part 2, *A Survey of California Conditions Relative to the Application of Water-Flooding,* was published in volume 45, no. 3, for July 1949.

** Assistant Professor of Petroleum Engineering, University of California, Berkeley, California. Manuscript submitted for publication April 1, 1949.

[1] Muskat, Morris, Production research—present and future: Paper presented before a meeting of the Mineral Industry Education Division, Am. Inst. Min. Eng., Berkeley, California, February 13, 1949.

[2] Scott, D., Water-flooding research is essential: Prod. Monthly, vol. 11, no. 7, p. 27, May 1947. Paper presented before A. P. I. Eastern Division Meeting, Pittsburgh, Pa., April 16-18, 1947.

[3] Hughes, R. V., Importance of research in secondary recovery by water-flooding, Petroleum Engineer, vol. 17, no. 12, p. 180, August 1946.

[4] Andrus, D. T., Secondary recovery research: Interstate Oil Compact Quarterly Bull. vol. 5, no. 2, pp. 16-26, August 1946.

[5] Van Wingen, N., and Johnston, N., Current concepts of secondary recovery: Am. Petroleum Inst., Drilling and Petroleum Practice 1946, pp. 196-208.

Past Research

A moderate amount of water-flooding research has been undertaken by California oil companies and educational institutions throughout the last two decades. The work has been sporadic in nature and little has appeared in the published literature as to the results obtained. Most of this work has been of such a nature as to add to the general fund of knowledge in the field of water-flooding but little consideration was apparently given to the special problems encountered in California.

Some of the earliest work on the subject was reported by Uren and Fahmy [6] in 1927. In this work flooding experiments using unconsolidated sands were carried out. Some general conclusions as to the effects of viscosity, interfacial tensions, rates of advance, etc., were reached and these conclusions have been more or less substantiated by recent work. Unfortunately, this work seemed to indicate that water-flooding would not be successful in California fields and may have been an important factor in retarding the application of water-flooding in this state.

A few years after this work, the importance of edgewater drive as a force in the expulsion of petroleum from reservoir rocks was beginning to be recognized. In 1931 Herold made the statement that "in California fields water encroachment is not an unnecessary evil but a very necessary one." [7] Prior to this era, water was considered a nuisance rather than an aid to oil production. Several papers appeared in the literature during this and the following few years reviewing the characteristics of edgewater encroachment in California fields. One of the better papers on this subject was prepared by Wilhelm, Davis and Clark.[8] The role which water plays in the production of petroleum was rather clearly defined and California fields were classified according to the effectiveness of edgewater drive. Few California fields were found to have sufficiently active edgewater drives to maintain reservoir pressure and total production at constant values throughout the productive life of the field. Many fields were included in a second group in which edgewater encroachment was effective but not sufficiently so to keep pace with the rapid withdrawal of oil. Most of these fields were developed rapidly and produced at unrestricted rates, and there was an attendant rapid depletion of reservoir energy. After passage of the period of flush production, withdrawal rates decreased to a point where edgewater encroachment became effective. Had these fields been produced at lower rates initially, efficient edgewater encroachment might have been realized throughout the productive life of the field. A third group of California fields included those in which the edgewater drive was effective only in a secondary way, this being due to one of two causes: (1) lack of sufficient head to permit flow; (2) inability of water to penetrate the producing formations because of their low water permeability. The fourth group included those fields in which expulsion was due entirely to the expansion of gas and to gravity drainage with water playing no role in the expulsion.

---

[6] Uren, L. C., and Fahmy, E. H., Factors influencing the recovery of petroleum from unconsolidated sands by water-flooding: Am. Inst. Min. Eng. Trans., vol. 77, p. 318, 1927.

[7] Herold, S. C. in discussion of Encroachment of edgewater at Santa Fe Springs, by D. K. Weaver: Am. Inst. Min. Eng. Petroleum Dev. and Tech., p. 157-163, 1931.

[8] Wilhelm, V. A., Davis, E. L., and Clark, W. A., Characteristics of edgewater encroachment in California fields, Oil Weekly, vol. 71, no. 4, p. 13, 1933.

This period of advance in petroleum technology was important for it demonstrated that the operators were becoming aware of the importance of edgewater encroachment, this in itself laying the groundwork for subsequent water-flooding. A few further observations of the water encroachment characteristics of California fields should be cited because of their importance in this connection. Jensen and Stevens [9] have given an interesting case history of the water problems in the old McKittrick field. Flush production in this field lasted for a period of almost 15 years, including the development period. No water was produced early in the life of the field but as the flush production period ended water production increased. The following 6 years saw continually increasing water invasion up to a very pronounced maximum. Continued heavy withdrawals of water from the apparently exhaustible source, caused a subsequent decrease in water invasion. This decline continued until by the end of the second 15-year period, water was being produced at a rate comparable with that at the end of the flush production period. A similar phenomenon has been observed in several other California fields where inefficient use has been made of exhaustible edgewater sources.

Nickerson [10] has related an interesting early approach to the problem of control of edgewater drive in interbedded formations, citing as an example the Elk Hills field. It was noted in this field that the production from clean wells increased month by month until water cuts reached about 5 percent. At this point, the decline curve dropped off rapidly with greatly increased water cuts. By plugging the bottom 10 to 20 feet of the well, water production was practically eliminated and the cycle was then repeated for the next higher portion of the formation. This again indicates that considerable thought was being given to the proper control and utilization of edgewater drive.

In 1938 F. G. Miller and H. C. Miller [11] again brought into focus the problem of edgewater encroachment in their comprehensive review of the literature on the subject. This was followed by a report of laboratory investigations by F. G. Miller [12] on the characteristics of encroachment. The results showed that within a range of low rates of encroachment, greater recovery efficiency was obtained at higher rates. These results were in direct conflict with somewhat earlier work done by Rankin [13] and others. This controversy is still unsettled at the present time.

The ensuing period saw considerable research in California devoted not directly to water-flooding but to the newly developed and closely allied field of reservoir mechanics. Methods of core analysis and means of interpreting the results obtained underwent considerable development and investigation. The concepts of multi-phase flow and relative permeabilities received a good deal of attention and electrical logging methods came to the fore. Secondary recovery research, although unreported in the literature, was being conducted by several organizations up to and into the war period. Although this work was sidetracked by more imminent problems directly concerned with the war effort, some phases of secondary recovery research were continued. It was during this period that the two important water-injection tests in California were commenced.

---

[9] Jensen, J.. and Stevens, J. B., Water problems in the McKittrick oil field, Am. Inst. Min. Eng., Petroleum Dev. and Tech., pp. 164-167, 1931.

[10] Nickerson, C. M., in discussion of Effect of edgewater on recovery of oil by H. H. Wright: Am. Inst. Min. Eng., Petroleum Dev. and Tech., pp 168-177, 1931.

[11] Miller, F. G. and Miller, H. C., Resume of problems relating to edgewater encroachment in oil sands: U. S. Bur. Mines Rept. Inv. 3392, March 1938.

[12] Miller, F. G., A laboratory study of water encroachment in oil-filled sand columns. U. S. Bur. Mines Rept. Inv. 3595, Oct. 1941.

[13] Rankin, D. R., A laboratory investigation of the effect of rate on the recovery of oil by water-flooding: Paper presented before Am. Inst. Min. Eng., Petroleum Div. Meeting, October 19, 1939, Los Angeles.

Toward the close of the war and shortly thereafter several papers pertinent to this subject appeared in the literature. These papers were significant for they were the first reports of investigations directed specifically to California problems. The work of Johnston and Beeson, discussed in Part 1 of this report, demonstrated the importance of the physical changes which may occur in California reservoir sands when various fluids are passed through them. Cerini, Battles, and Jones[14] investigated the factors influencing the plugging characteristics of injection water for the Richfield field. Through this work methods of testing and treating injection water were developed. Van Wingen and Johnston[15] reviewed secondary recovery projects in California and discussed the future of secondary recovery in this state. In the latter work, the conclusions reached, which were not particularly favorable, were based on a comparison of California conditions with the very dissimilar conditions in other areas. It is apparent that special techniques will have to be developed in California to cope with these special problems.

Some of the most recently reported work was that of Dykstra and Parsons.[16] Through this investigation there was developed a means of predicting oil recovery by water flood in cases where sufficient physical data were available. Such matters as variable physical properties and limiting values of the mobility ratio were considered. Advanced studies of this problem are in progress, and the results should prove to be of great value.

It should be emphasized that the foregoing review is far from the complete picture of past water-flooding research in California. It is felt to be sufficiently complete however, to demonstrate the changing trend toward investigations of the basic problems involved in water-flooding California fields and to show the increasing interest in the subject throughout the years.

Current Research Activities

The increased interest in water-flooding and related research has given rise to a difficult problem, since many organizations are conducting or considering programs of varying scope and magnitude. Without coordination of this work, costly and needless duplication of effort will result and the advancement of knowledge in this field will be impaired.

Water-flooding research in California can be divided into two categories: (1) Fundamental and applied laboratory and field investigations such as are currently in progress by the oil company research organizations and by educational institutions; (2) Engineering field studies and experimental projects such as are being conducted by the U.S. Bureau of Mines and the oil companies. The following paragraphs are a summary of this work.

---

[14] Cerini, W., Battles, Jones, G., Some factors influencing the plugging characteristics of oil-well injection water: Am. Inst. Min. Eng., Petroleum Dev. and Tech., pp. 52-63, 1946.

[15] Op. cit.

[16] Dykstra, H. and Parsons, R. L., The prediction of oil recovery by water flood: Am. Petroleum Inst., Div. Prod., Paper 801-24K, May 1948.

The Interstate Oil Compact Commission has been conducting a vigorous campaign to promote and coordinate secondary recovery research. The aims of the Commission are outlined as follows:[17]

1. Encourage legislation permitting unitization of oil fields to permit the application of secondary recovery.
2. Collect and study production statistics and well records in all areas having secondary recovery possibilities.
3. Encourage research by states on methods of increasing oil recovery and periodic review of all important research in progress by educational institutions and industrial and research laboratories.
4. Maintain contact with all federal agencies having relations with the oil and gas industry.
5. Coordinate with other organizations interested in secondary recovery.

The Commission emphasizes that it does not propose to engage in secondary recovery research but that it does propose solely to accumulate, coordinate, and distribute information, and lend its assistance and encouragement to states, educational institutions, and private companies in expanding their programs. In line with this policy, questionnaires were sent to many universities and colleges to determine the nature and extent of research in progress or contemplated, personnel, funds, and facilities available, and other information of a similar nature. As California is not a participating member of the compact, direct benefits from this program may not be realized. Nevertheless, California operators and educational institutions will profit by the free interchange of information proposed by the Commission.

The Gavin Amendment of Public Law 443 (Synthetic Liquid Fuels Extension Act) passed by Congress March 15, 1948, authorized the U. S. Bureau of Mines to undertake a program of production research on secondary recovery from stripper oil fields. In addition to the important contribution the Bureau of Mines will make toward increasing the knowledge and application of secondary recovery, the passage of this Act shows that the importance of such work has been recognized. This should give stimulus to other groups and to the industry as a whole. In formulating the Bureau's program three general principles have been considered: (1) emphasis on those problems needing first attention in industry; (2) avoidance of unnecessary duplication of work being done by other research groups; (3) smoothing out of peaks and valleys of research activities.[18] The program, which will cover all secondary recovery methods, is divided into three main types of problems: (1) fundamental research; (2) applied research on special engineering problems; (3) engineering field studies. Fundamental research will be restricted primarily to a study of the nature of surface forces in petroleum reservoirs and their effects on displacement and flow through porous media. Applied research problems, some of which are under investigation at the present time, include: the use of explosives in well shooting; selective plugging of air-gas injection wells; fundamental studies of water chemistry, taking into account the effect of changes in pressure and contamination with connate water; flooding patterns; and many other problems which will arise as the program progresses. Engineering field studies will be made in each district to evaluate the success of existing secondary recovery projects and to study other fields as to their secondary recovery possibilities. Work done by the several districts will be carefully coordinated

---

[17] Foster, Earl, Plans and purposes of Interstate Oil Compact Commission dealing with secondary recovery operations: Am. Petroleum Inst. Prod. Bull. 233, vol. 27, no. 4, pp. 13-17, 1947.

[18] U. S. Bureau of Mines, 1948 Annual Report on Synthetic Liquid Fuels, Part IV, Secondary Recovery, Rept. Inv. 4458, January 1949.

The Petroleum Field Office of the U. S. Bureau of Mines in San Francisco, under the direction of Mr. H. C. Miller, has recently begun its phase of the work. Dr. A. G. Loomis and several assistants have been retained to undertake the work in the California area. This group is engaged at the present time in a comprehensive survey of the existing secondary recovery projects in California. After completion of this work, which will take several months, the group will begin a study of other California fields relative to their secondary recovery possibilities. Some laboratory work will be undertaken in conjunction with these surveys but laboratory research may be confined to problems unique to California conditions.

The educational institutions in California should become more interested in fundamental research relating to secondary recovery. Prospects that this will be the case are borne out by the recent appointment of Dr. S. T. Yuster to head petroleum engineering research at the University of California at Los Angeles. Although plans have not been formulated as yet, the appointment of such a noted expert on water-flooding as Dr. Yuster will have a far-reaching significance.

The Stanford University Research Institute has also recently announced the appointment to their staff of Dr. R. V. Hughes, formerly Research Director of the Penn Grade Crude Association. Although again final plans have not been announced, certain phases of water-flooding research are to be undertaken under the very capable direction of Dr. Hughes. One of the proposed problems will deal with the effects of clays in secondary recovery.

The University of Southern California has in progress a secondary recovery research program in which the emphasis is being placed on recovery from typical California oil sands. Closely associated with this work is a second project devoted to a study of the electrical resistivity of saturated and partially saturated oil sands.

A water-flooding research program is in progress at the University of California. At the present time three topics are under investigation: mineralogical and physical classification of California oil sands; the clay content of California oil sands and its influence on water permeabilities; and further studies of the "mobility ratio" and how it is influenced by clay content. The work on clay analysis is being done in cooperation with the Division of Ceramic Engineering. At the present time this work is sponsored and supported wholly by the Engineering Research Projects of the University and its progress is dependent upon the work of graduate students and part-time research assistants. It is hoped that the project will be expanded as additional support and facilities become available.

In addition to the above research, related work is being conducted by the Department of Geology and Geophysics at the University of California. A thin-section study of cementation is furnishing additional information on the nature of the pores of California oil sands. A second project in progress in this department, an investigation of the physical significance of the formation factor in electrical logging, is also an important phase of water-flooding research.

Problems in the Application of Water-Flooding in California

The problems which will beset the water-flooding operator in California are many and varied. It is convenient, however, to classify them into two groups, legal and physical. The following is an attempt to summarize the more important of these problems.

Legal Problems

Legal difficulties may present formidable problems to the water-flooding operator. Townlot drilling and diversified land ownership are characteristic of many California fields and will increase the inherent difficulties of unitization. Although water-flooding has been successfully applied in other areas without unitization, unit control of a pool or a portion of a pool within the field would be desirable. The alternative of small-scale, non-unitized projects would not only be less profitable but would increase the possibilities of legal attack by unsympathetic neighboring interests. To overcome this difficulty all parties concerned should be educated in the benefits of secondary recovery. A sound argument based on laboratory and field research and analysis will be the best possible incentive to achieve the necessary cooperation.

The limited state legislation which might assist the operator in instituting secondary recovery operations is Section 3301 of the Public Resources Code, relative to the formulation of agreements for cooperative development. This section of the code states that in the interests of preventing unreasonable waste of oil and gas, the parties concerned may enter into agreements for cooperative development and operation, including production control and gas injection. Such an agreement once entered binds successors and asigns and is enforceable by law. Although this type of legislation is a step in the right direction, more rigorous laws should be enacted to compel cooperation in secondary recovery operations when it can be demonstrated that such action is essential to the public welfare.

Physical Problems

There are many problems of a physical nature with which the water-flooding operator will have to deal. Many of these problems may be deduced at the present time; others will arise as field developments are expanded. It is difficult to judge the relative magnitude of these problems but an analysis of Parts 1 and 2 of this paper discloses the following to be important research topics.

1. *The Effects of Gravity Segregation in Water-Flooding.* Most of the fields in California which might be considered for water-flooding have from moderate- to steep-dipping productive formations. The intensive blanket flooding employed in the low-dipping formations common to other areas may not, therefore, be practical in most California fields. The effects of gravity segregation will be important in these steeper beds and up-dip flooding may have to be employed. This does not appear to be an unfavorable situation, for gravity segregation, if properly utilized, should be beneficial to the flooding process.

Experiments should be conducted to determine the importance of gravity segregation in water-flooding. This might be accomplished by comparing flooding behavior in cores or sandpacked tubes mounted horizontally, vertically, and in inclined positions.

2. *Characterization of the Mineral Content of California Reservoir Sands, with Emphasis on the Clay Content.* Because of the limited amount of information available regarding the mineral content of California reservoir sands, especially the clay content, an investigation of this nature should yield valuable information. Developing methods of sampling, preparation and analysis of natural core specimens will be an important phase of this work. Accepted methods of petrographic analysis may be used in the identification of sand grain minerals and differential thermal analysis and x-ray diffraction methods may be employed in clay determinations.

As mentioned earlier, studies of this nature are in progress at the University of California at the present time. Carefully preserved and well identified cores from fields throughout the state are being supplied by several oil companies. These cores are subjected to very careful analyses including: porosity; air, fresh water, and salt water permeabilities; grain-size analysis: heavy mineral separation; petrographic analysis; and differential thermal analysis of clay fractions. Difficulties have been encountered in the quantitative determination of the clay content of some California cores. It is hoped that a method may soon be developed whereby the reactive clay content of these cores may be deduced by the comparison of water and air permeabilities. This work should not only be continued but it should be expanded to provide sufficient information to characterize California reservoir sands.

3. *An Investigation of the Nature of the Pores of California Reservoir Sands.* The important effects of pore shape, size, and size distribution on permeability and displacement phenomena have been discussed earlier in this report. Since pore size and shape might have an influence on injection rates, this investigation should be initiated at an early date.

As already mentioned, a thin-section study of cementation in progress in the Department of Geology at the University of California is furnishing additional information on the nature of the pores of California oil sands. The same cores as mentioned in (2) above are being used in this work. The work should be expanded to include pore-size distribution measurements employing apparatus similar to that available in the Petroleum Engineering Laboratories of the University. The use of wax molds might be a further aid in this study.

4. *Further Studies of the "Mobility Ratio" and How It Is Influenced by Clay Content.* The influence of water and oil viscosities and relative permeabilities on water-flooding can best be demonstrated by consideration of the "mobility ratio." The range of values of this ratio under California reservoir conditions should be investigated and limiting values of the ratio for effective water-flooding should be determined.

In examining further the mobility ratio given as:[19]

$$\mathrm{MR} = \frac{k_o \, \mu_w}{k_w \, \mu_o}$$

---

[19] Op. cit.

where: MR = mobility ratio
k_w = relative permeability to water
k_o = relative permeability to oil
μ_o = viscosity of the oil
μ_w = viscosity of the flood water

it will be noted that a low ratio is desirable for a stable oil-water interface and effective flooding. The terms k_o, μ_w, and μ_o are essentially constant quantities and could not be altered sufficiently to influence the value of the ratio appreciably. If, however, the low fresh water permeability of California reservoir sands is a result of clay swelling, it might prove feasible to reduce k_w, and likewise the mobility ratio, by employing an injection water which will promote a known and controlled amount of clay swelling. This is contrary to the normal procedure where an attempt is made to restrict clay swelling to a minimum but it might prove to be an effective means of overcoming the disadvantages of the high viscosity of many California crude oils. Considerable research should be undertaken on this phase of the problem.

5. *Polar Impurities in California Crude Oils and Their Influence on Water-Flooding.* The presence of polar impurities in the oil phase has a pronounced influence on the wettability and displacement characteristics of mineral grain surfaces. Analyses should be made to determine the presence or absence of polar impurities in California crudes. Further tests should be made to determine the effectiveness of these impurities in altering the wettability and displacement characteristics of California reservoir sands.

6. *Water Treatment to Control the Swelling of Clays Present in California Reservoir Sands.* When the types and amounts of clays common to California reservoir sands have been determined, methods of treating injection water to control clay swelling should be developed. In this work, the types of water which may be available for injection, such as subsurface brines and possibly ocean water, should be considered.

7. *Measurements of Liquid-Solid Interfacial Tensions.* No direct means of measuring liquid-solid interfacial tensions is available at the present time. The ability to measure these forces would be of great help in the investigation of surface and displacement phenomena. A method of measuring interfacial tensions, similar to the method used in measuring the adsorption of gases on solids, might be considered.

8. *A Comparison of Recovery Efficiencies of Water-Wet and Oil-Wet Sands as a Function of Rate of Injection.* The question as to whether most California reservoir sands are oil-wet or water-wet must first be answered. A comparison of the recovery efficiencies for these two conditions at various rates of water advance will yield valuable information.

9. *Physical Significance of the "Formation Factor" in Electrical Logging and its Measurement Under Reservoir Conditions.* The value of electrical logging in water-flooding can not be over-emphasized. Considerable research is needed on many phases of the subject. The physical significance of the "formation factor" is just one of many concepts which have not been adequately evaluated. An investigation of this nature is currently in progress in the Division of Geophysics at the University of California. Full cooperation and encouragement should be given in this work.

10. *Nature of the Fluid Distribution in Reservoir Pore Spaces.* The distribution of fluids in reservoir sand pore spaces undoubtedly influences displacement and flow phenomena. The nature of this distribution and the factors controlling it should be investigated. These have proven to be difficult problems and extensive experimentation will be required for their solution.

11. *The Influence of Injection Rates and Pressures on Recovery Efficiency.* So much confusion seems to exist as to the most effective rates and pressures for injection that an investigation of these factors is imperative. This work should be done in close cooperation with that described in (8) above.

12. *An Investigation of the Application of Selective Plugging Methods to California Reservoir Sands.* The lack of uniformity in permeability of California reservoir sands will make it necessary to adopt methods of selectively plugging high permeability sands for efficient injection. Satisfactory methods of plugging are apparently not available for water injection purposes and, in addition, California reservoir sands may present further problems in this connection. Although a part of this work may be done in the laboratory, field tests will be necessary to complete the investigations.

Conclusions and Recommendations

In analyzing the foregoing dissertation on the subject of water-flooding as a means of increasing California oil production, the following conclusions and recommendations appear to be justified:

1. If California is to maintain its position as one of the leading oil producing states, operators must resort to secondary recovery methods.

2. Although gas-injection methods might be used as an intermediate step, it appears that water-flooding must ultimately be employed in most cases to assure maximum recovery of oil.

3. There are two types of problems involved in the application of water-flooding, legal and physical.

   (a) All parties concerned must be educated in the benefits of water-flooding. Proper and sufficient legislation must be enacted to protect the secondary recovery operator from unnecessary interference with his work.

   (b) Physical problems are many and varied but not insolvable. Many of these problems are unique to California conditions and the mistake should not be made of attempting to apply operating principles which have been successful in other, but dissimilar, areas. Considerable laboratory and field research will be required to develop applicable operating practices.

4. One of the most vital needs in the advancement of a water-flooding research program is that of coordination of effort. Fowler makes the very pertinent statement that ''research is always competitive to a certain degree, but fortunately in most cases it is a healthy stimulating variety that spurs each group on to find some new fact which others may use to mutual advantage.''[20] This thought should be borne foremost in mind in developing a coordinated research program.

---

[20] Fowler, H. C., Secondary recovery research and the Bureau of Mines, preprint of address presented before the Interstate Oil Compact Commission meeting, May 7, 1948, Chicago, Illinois.

5. The following is a suggested means of accomplishing the above proposal (4):

    (a) Delegate a state or federal agency the task of overall coordination.

    (b) Assign fundamental research problems to properly qualified and equipped educational institutions and industry research organizations.

    (c) Delegate field and applied research to the U. S. Bureau of Mines and the oil companies.

6. As the State of California receives a large portion of its revenues from the petroleum industry, costs of the fundamental research work should be borne equally by the state and by the industry.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to the members of the staff of the University of California and others who so carefully reviewed the original manuscript of this report, and in particular to Professor L. C. Uren for his inspiration and guidance; to the California State Division of Oil and Gas for their kind assistance in supplying data for the report; and to Dr. Olaf P. Jenkins and his staff for their kind cooperation in the publication of the paper.

MATERIALS OF INORGANIC MINERAL ORIGIN USED IN THE RUBBER INDUSTRY

By Erle C. Zimmerman *

OUTLINE OF REPORT

Page
Introduction ---- 553
Specifications ---- 553
  Purity ---- 553
  Fineness ---- 554
  Color ---- 554
Description of inorganic mineral materials used in the rubber industry ---- 554

INTRODUCTION

A large variety of materials is used in the compounding of natural and synthetic rubber. These materials fall into two general classes, organic and inorganic.

The organic materials include the accelerators of vulcanization, age resistors, plastic resins, oils, waxes, asphalts, pitches, dyes and solvents, most of which have their source in coal tar or petroleum. The various types of carbon black used extensively by the rubber industry fall into the class of organic mineral materials and have their origin in petroleum and in natural gas.

Most of the materials of inorganic mineral origin are manufactured by methods involving chemical processes and are highly refined, purified, and produced in a fine state of particle size. Falling into this category are such materials as blanc fixe, precipitated calcium carbonate, basic magnesium carbonate, precipitated calcium silicate, precipitated silica, titanium dioxide, and zinc oxide. Other materials of inorganic mineral origin consist of the finely ground minerals such as talc, limestone, and mica. Still others such as clay and ochre occur naturally in a fine state of subdivision and may require only the removal of coarse impurities.

SPECIFICATIONS

All of the materials used in the compounding of rubber must meet rather exacting specifications for purity and fineness, and in many cases color is also important. Uniformity is desirable and necessary.

Purity

The degree of pureness or the amount of impurities present in a given material may vary considerably, depending upon the source of the material, the process used in its preparation, and the care exercised in its production. Three types of impurities are encountered: those which are harmful in rubber compounds and which will tend to cause deterioration in rubber products; those which will degrade the color of a colored rubber article; and those impurities which are inert and have no harmful effect on rubber products.

The dangerous impurities, those that tend to cause deterioration, are copper and manganese which, in many cases, must not be present in

---

* Firestone Tire & Rubber Company. Manuscript submitted for publication February 18, 1949.

amounts exceeding a few thousandths of one percent. Arsenic is undesirable, and materials showing radioactivity should be questioned. Free acid or alkali must be eliminated, or at least kept to a safe minimum.

Impurities that degrade color are lead, iron, cobalt, antimony, and other elements which have colored oxides or sulfides.

Inert impurities, which have no harmful effect, are oxides of aluminum, calcium, magnesium, barium, iron, titanium, and silicon, and possibly carbonates or sulfates of calcium, barium, and magnesium. A small amount of lead in the form of lead sulfate or lead oxide may not even be considered harmful in most cases. Zinc and cadmium also may be present in the form of oxides, carbonates, or sulfides.

Fineness

Rubber compounding materials must be produced in a fine state of subdivision and air-separated, levigated, hydro-classified, or otherwise treated to eliminate the objectionable coarse particles. The necessary fineness will vary, depending upon the nature of the material, the process or production method, and the specific use for which the material is employed.

In most cases, at least 95 percent of the material must pass through a 300-mesh screen, but in other cases 99½ percent must pass through a 325 mesh screen. In either case the bulk of the particles will be of diameters many times smaller than the meshes in a 325-mesh screen.

Coarse residues, even when present in small amounts, are objectionable in rubber compounding, hence almost without exception 100 percent of a material for use in rubber should pass through a 100-mesh screen and in some cases, 100 percent should pass through a 200-mesh screen.

Color

If a material is to serve the purpose of a color pigment for rubber, its purity must be carefully controlled, and special attention must be given to limiting the percentages of certain impurities which influence the color. This is especially true in the case of white pigments such as titanium dioxide, lithopone, and zinc oxides. The covering power of all color pigments is important and must be controlled.

DESCRIPTION OF INORGANIC MINERAL MATERIALS USED IN THE RUBBER INDUSTRY

A brief description follows of 32 of the common inorganic mineral materials used in the compounding of rubber. The description includes source, processes, degree of purity required, necessary fineness, and purpose for which the material is used; also the extent of use expressed as large, moderate, or small.

Carbon black made from natural gas and petroleum is the organic mineral material most extensively used in the compounding of natural and synthetic rubbers. There are some dozen different types and kinds of carbon black made by various processes which are used in the rubber industry. Nearly all of these carbon blacks are used as reinforcing fillers and are far superior in this respect to any of the mineral materials of inorganic origin. In the tire industry, for instance, three pounds of carbon blacks are used to one pound of the combined total of all of the 32 materials of inorganic mineral origin listed. The ratio is lower than this for mechanical goods.

Local sources of supply for many of the materials of inorganic mineral origin used in rubber are needed on the west coast. Lower-priced materials are also needed to compete with the carbon blacks. Improvement of the quality and reinforcing action of the materials of inorganic origin used in rubber compounding will be necessary if such materials are to compete with carbon black from the quality point of view.

Materials of Inorganic Mineral Origin Used in the Rubber Industry

(1) Asbestine
(2) Barite
(3) Blanc fixe
(4) Brown oxides of iron
(5) Cadmium yellow
(6) Calcium carbonate, precipitated
(7) Calcium carbonate, ground
(8) Calcium silicate
(9) China clay (kaolin)
(10) Clay (rubber clay)
(11) Diatomaceous silica
(12) Hydrated lime
(13) Lithopone
(14) Litharge
(15) Magnesium carbonate, basic
(16) Magnesia, calcined
(17) Mica
(18) Ochre
(19) Red lead
(20) Red oxide of iron
(21) Selenium
(22) Silica
(23) Sulfur
(24) Talc
(25) Tellurium
(26) Titanium dioxide
(27) Ultramarine blue
(28) Zinc oxide, French process
(29) Zinc oxide, American process
(30) Zinc carbonate
(31) Zinc sulfide
(32) Zinc yellow

(1) Asbestine (magnesium silicate) is a moderately pure form of talc, usually white or light colored. It is made from natural magnesium silicates, which are ground to the degree of fineness desired. It contains 60 to 65 percent silica and 30 to 33 percent magnesium oxide; it also contains impurities such as silicates of iron, aluminum, calcium, silica, magnesium, and calcium carbonates. It should be reasonably free from copper and manganese.

It is used with natural and synthetic rubbers as an inexpensive inert filler.

Fineness is normally 90 percent or more through a 300-mesh screen.

Use is moderate.

(2) Barite (ground natural barium sulfate) is ground and levigated in settling tanks from the mineral of the same name. It should run 93 percent or more barium sulfate; the usual impurities are silica and iron oxide. It should not contain more than 0.005 percent copper and not more than 0.04 percent manganese. It is used as an inexpensive inert filler for both natural and synthetic rubber.

Normally, the fineness runs at least $99\frac{1}{2}$ percent through a 300-mesh screen but the more finely ground types bring higher prices.

Use is moderate.

(3) Blanc fixe (precipitated barium sulfate) is made from barite by reducing with coal, after which the resulting barium sulfide is dissolved in water and the barium sulfate precipitated by adding sodium sulfate; it is also made from witherite (natural barium carbonate) by dissolving in hydrochloric acid and adding sodium sulfate; or direct by dissolving witherite with hot dilute sulfuric acid; also made as a by-product in the manufacture of hydrogen peroxide.

Blanc fixe is used with natural and synthetic rubbers as a high-grade inert filler.

It should run at least 97 percent barium sulfate; permissible impurities are calcium sulfate and calcium and magnesium silicates. It should contain not more than 0.0005 percent copper, nor more than 0.005 percent manganese. Fineness should be 99 percent or more through a 325-mesh screen and 100 percent through a 200-mesh screen.

Use is moderate.

(4) Brown oxides of iron are dissolved in sulfuric acid and the iron is precipitated as the hydrated oxides which are partially oxidized. They can also be made from by-product ferrous sulfate and are available in various shades. Certain impurities are permitted but not more than 0.01 percent of copper, nor more than 0.05 percent of manganese. At least 95 percent should pass through a 300-mesh screen and 100 percent should pass through a 100-mesh screen.

These oxides are used in natural and synthetic rubbers as color pigments.

Use is small.

(5) Cadmium yellow is cadmium sulfide produced by precipitating the sulfide from soluble salts of cadmium with sodium sulfide. It can also be produced by adding barium sulfide solution to a solution of cadmium sulfate, and when made in this manner, cadmium yellow will contain a large amount of barium sulfate.

Cadmium yellow should be free from copper and manganese and 99 percent or more should pass through a 325-mesh screen.

It is used in natural and synthetic rubbers as a bright permanent yellow pigment.

Use is small.

(6) Precipitated calcium carbonate is obtained as a by-product in the manufacture of magnesia from dolomite, which is a mixture of calcium and magnesium carbonates. The dolomite is first calcined and dissolved in water, and then carbon dioxide is passed through. The calcium carbonate is removed as a precipitate.

Precipitated calcium carbonate, is also obtained in the manufacture of bicarbonate of soda and washing soda. Precipitated calcium carbonate, of the finest particle size is produced by passing carbon dioxide through purified lime water.

The ordinary precipitated calcium carbonate should contain at least 94 percent of calcium carbonate and not more than 4 percent magnesium carbonate. Copper should not exceed 0.002 percent and manganese not more than 0.005 percent. In fineness, 99½ percent should pass a 300-mesh screen. The super-fine calcium precipitated carbonate runs lower in impurities, and 99.8 percent should pass a 300-mesh screen.

This material is used in various degrees of purity as a mild reinforcing filler and as an inert filler in the compounding of natural and synthetic rubbers.

Use is large.

(7) Ground Calcium Carbonate. Ordinary ground limestone and marble are used. The permissible degree of purity covers a considerable range, but the material should run at least 92 percent calcium carbonate, and the oxides of iron, magnesium, and aluminum should not exceed 1½ percent each. Copper should not exceed 0.005 percent and manganese should not exceed 0.05 percent. Ground calcium carbonate is available in many degrees of fineness. For the finest grade 99½ percent should pass a 325-mesh screen; for ordinary grades 96 percent should pass a 300-mesh screen and 100 percent should pass a 100-mesh screen.

It is used in natural and synthetic rubbers as a mild reinforcing filler and also as an inert filler.

Use is large.

(8) Precipitated calcium silicate, is made by treating lime water or a solution of calcium chloride with sodium silicate solution under special conditions which give fine particle size. The purity should run 96 percent; the silicates of iron, magnesium, and aluminum are permissible impurities. Precipitated calcium silicate should not contain more than 0.002 percent copper, nor more than 0.01 percent manganese. Fineness should be 99 percent through a 325-mesh screen and 100 percent through a 200-mesh screen. It is used in synthetic rubber and latices as an inert filler.

Use is small.

(9) China Clay consists of hydrous aluminum silicate formed as a residue from the decomposition of granite and other rocks containing feldspar. In many cases it is deposited from a body of water as a sediment. China clay or kaolin is distinguished from other clays by its white color. There are many types and kinds. China clay is purified and prepared by wet grinding, hydroclassifying, drying, and dry grinding. Continuous-flow centrifuges are also used in the purification of china clay.

China clay should be almost free from oxides of iron, but may contain oxides of titanium, magnesium, calcium, sodium, and potassium. It should be reasonably free from copper and manganese.

The fineness should run 99.5 percent through a 300-mesh screen, 100 percent through a 100-mesh screen.

China clay is used in natural rubber, synthetic rubber and latex as an inert filler.

Use is small.

(10) Clay (rubber clay) is similar to china clay, but most of it contains a few percent of iron oxide, which gives it a buff or cream color. Rubber clays are of sedimentary origin. They are usually prepared by drying, dry grinding, and air separation. Chemically, such clays contain 35 to 40 percent aluminum oxide and 40 to 45 percent silica, less than 10 percent oxides of iron, titanium, etc., about 15 percent combined water, and 1 percent or less of free moisture. Rubber clay should contain not more than 0.005 percent copper and not more than 0.01 percent manganese. In grinding, 99.5 percent should pass through a 300-mesh screen and 100 percent should pass through a 100-mesh screen.

Rubber clay is used in natural and synthetic rubbers and in latices as a mild reinforcing filler; large amounts are also used as inert filler.

Use is large.

(11) Diatomaceous silica consists of siliceous skeletons of small aquatic plants, which occur in large deposits. Chemically it is silicon dioxide in a high degree of purity. It is known under different names such as kieselguhr, diatomite, infusorial earth. It is calcined and ground and air classified, a variety of different processes being used. It should contain 90 percent or more silicon dioxide, and permissible impurities consist of oxides of iron, aluminum, etc. It is ground to various degrees of fineness, but normally 99 percent should pass a 300-mesh screen and 100 percent should pass a 100-mesh.

It is used in natural and synthetic rubbers as an inert filler.

Use is small.

(12) Hydrated Lime. Limestone is calcined to drive off carbon dioxide and slaked in water to form calcium hydroxide. Grit and foreign material are removed. There are various grades depending on calcium content; when made from dolomite lime will run high in magnesium oxide. Hydrated lime high in calcium will run 92 percent or better calcium hydroxide. The fineness should be 95 percent or more through a 300-mesh screen.

It is used in natural and synthetic rubbers and in latices as an accelerator activator.

Use is small.

(13) Lithopone consists of 30 percent zinc sulfide and 70 percent barium sulfate produced by the double reaction of a solution of zinc sulfate and barium sulfide. It should be reasonably free from impurities and contain not more than 0.002 percent copper nor more than 0.01 percent manganese. For fineness, 99½ percent should pass through a 325-mesh screen.

It is used with natural and synthetic rubbers as a white pigment and is also used as an inert filler.

Use is moderate.

(14) Litharge (lead monoxide) is made by oxidizing molten lead with a blast of air. It should be reasonably free from impurities and should not contain more than 0.005 percent copper nor 0.01 percent manganese. Fineness should be 99 percent through a 300-mesh screen. It serves as an accelerator activator for natural rubber, GR-S, and nitrile rubbers, and as a vulcanizing agent for neoprene.

Use is small.

(15) Basic magnesium carbonate is made from dolomite rock, which is composed of a mixture of magnesium carbonate and calcium carbonate. The crushed rock is calcined to drive off the carbon dioxide so that the oxides of magnesium and calcium are left. These are suspended in water and hydrated and treated with carbon dioxide under pressure. The calcium hydroxide is precipitated as calcium carbonate, while the magnesium acid carbonate remains in solution. The two carbonates are separated by filtration and the magnesium carbonate solution is heated to decompose the acid carbonate and form basic magnesium carbonate as a precipitate. The latter is filtered out, dried, and pulverized.

Basic magnesium carbonate is available in different degrees of purity, depending on how thoroughly the calcium carbonate was removed, and the purest will run 99 percent basic magnesium carbonate. The usual impurities are calcium carbonate and the oxides of iron and aluminum. It should not contain more than 0.002 percent of copper nor more than 0.005 percent of manganese. The fineness should run at least 99 percent through a 300-mesh screen and 100 percent through a 100-mesh.

It is used in natural and synthetic rubber as a reinforcing filler.

Use is moderate.

(16) Calcined magnesia is magnesium oxide made by calcining basic magnesium carbonate. The impurities will, therefore, be the same as in basic magnesium carbonate. Fineness should be at least 98 percent through a 300-mesh and 100 percent through a 100-mesh screen.

Calcined magnesia is used with both natural and synthetic rubbers. It serves as a mild accelerator activator and also as a reinforcing filler.

Use is moderate.

(17) Mica (muscovite, etc.) is an orthosilicate of potassium and aluminum. The sheets of mica (crude) are crushed and pulverized, and foreign matter such as iron oxide and clay are flushed and settled out of water suspension.

Mica is available in a range of shades and in different degrees of fineness. The highest quality for use in the rubber industry should have fineness of 99 percent through a 300-mesh screen and 100 percent through a 100-mesh.

Mica is used with natural and synthetic rubbers as an inert filler and as a dusting agent.

Use is moderate.

(18) Ochre is a mixture of limonite, iron ore and clay. The crude ore is washed to remove sand and other impurities, and further purification is carried out in conical classifiers. It is dewatered, dried and pulverized. The composition varies considerably. It should not contain more than 0.002 percent copper nor more than 0.05 percent manganese. For fineness, 99 percent should pass a 300-mesh screen and 100 percent should pass 100-mesh.

It is used in natural and synthetic rubber as a yellow pigment.

Use is small.

(19) Red lead is made by heating lead monoxide in a furnace. It should not contain more than 0.005 percent copper nor 0.01 percent manganese. Ninety-nine percent should pass through a 300-mesh screen.

It is used as an accelerator activator for natural rubber, GR-S, and nitrile rubbers, and as a vulcanizing agent for neoprene and butyl.

Use is small.

(20) Red oxide of iron is made by heating iron sulfate in various types of furnaces. After calcination, the iron oxide is washed to remove soluble salts, filtered, dried, and pulverized. It usually contains 98 percent or more iron oxide, the impurities being oxides of various other metals and silica. It should not contain more than 0.01 percent copper nor more than 0.05 percent manganese. In fineness 99 percent should pass a 300-mesh screen. It is used with natural and synthetic rubbers as a red color pigment.

Use is small.

(21) Selenium of a good degree of purity and fine particle size is used as a vulcanizing agent for natural rubber.

Use is small.

(22) Silica is finely ground quartz or sand used in various degrees of purity and fineness. It is also made in a very fine state of subdivision as a precipitate by adding dilute acid to a sodium silicate solution. In fineness, 99 percent should pass through a 300-mesh screen.

It is used as an inert filler in natural and synthetic rubbers.

Use is small.

(23) Sulfur is purified and ground to various degrees of fineness. For use in rubber, it should not be too fine; 80-90 percent through a 200-mesh screen and 100 percent through an 80-mesh disperses best in rubber.

It is used with natural and synthetic rubbers and latices as the vulcanizing agent.

Use is large.

(24) Talc is pure hydrous magnesium silicate. Many other well-known pigments such as soapstone, steatite, and asbestine, may contain from 50 to 90 percent talc, which is formed in various ways by alteration of rocks. After mining the ore is crushed and ground.

Talc is available in different degrees of purity; color varies from white to dark gray, and there are many different degrees of fineness. The best will run 99 percent through a 325-mesh screen.

Talc is used as a dusting powder and also as an inert filler for both natural and synthetic rubber.

Use is large.

(25) Tellurium of a fair degree of purity and fine particle size is used in the same manner as selenium.

Use is small.

(26) Titanium dioxide is obtained from the mineral ilmenite. The pulverized ore is treated with hot sulfuric acid and the solution is diluted, filtered, and otherwise purified. The titanium sulfate is hydrolized, forming the fine colloidal titanium dioxide, which is then calcined in a rotary kiln. Titanium dioxide normally runs from 97 to 99 percent pure and will normally contain some silica. It should not contain more than 0.002 percent copper nor more than 0.01 percent manganese. The fineness should run 99½ percent through a 325-mesh screen. Titanium dioxide is also sold to the trade as a blend containing barium sulfate or calcium sulfate. It is used in natural and synthetic rubber as a pure white pigment.

Use is moderate.

(27) Ultramarine blue is a double silicate of sodium and aluminum containing some sulfides. It is produced artificially from china clay, sulfur, soda ash, and charcoal. It is available in various shades and in different degrees of fineness. It should be reasonably free from copper and manganese. It is used in natural and synthetic rubber for light blue colors, and a small amount is used in pure white rubber compounds to remove traces of yellow color.

Use is small.

(28) Zinc oxide, French process. Zinc metal is first obtained by various processes from a variety of zinc minerals such as zinc blende, willemite, franklinite, and zincite. The zinc sulfide ores are roasted to convert them into zinc oxide. The impure zinc oxide or zinc oxide ores are mixed with an excess of anthracite coal or coke and charged into a furnace. The zinc oxide is reduced to metallic zinc, which vaporized in the heat of the furnace and was driven off; when cooled, the metallic zinc condenses. Some furnaces are electrically heated. The metallic zinc may be purified electrolytically to remove copper, lead, and many other impurities. The metal is then vaporized in a retort heated externally, and the vapor is brought in contact with air, which oxidizes it to zinc oxide. The zinc oxide is collected in bags.

French process oxide should not contain more than 0.003 percent copper, nor more than 0.005 percent manganese and should contain less than 0.10 percent lead. In fineness 99.9 percent should pass through a 300-mesh screen and 100 percent should pass a 100-mesh.

French process oxide is used in natural rubber and synthetic rubbers and in latices as a pure white pigment, accelerator activator or reinforcing filler.

Use is large.

(29) Zinc oxide, American process. In the American process the zinc ore is mixed with anthracite coal and fired on an open grate. The zinc oxide vapor coming from the furnace is collected in bags. The American process zinc oxides are not as pure as those made by the French process and contain higher percentages of lead, usually in the form of lead sulfate. Not more than 0.003 percent copper nor 0.005 percent manganese should be present, and the lead should not exceed 0.50 percent as the sulfate. In fineness, 99.9 percent should pass through a 300-mesh screen and 100 percent should pass through a 100-mesh.

It is used in natural and synthetic rubbers and latices as an accelerator activator, reinforcing filler and as a white pigment.

Use is large.

(30) Zinc carbonate should have the same degree of purity and fineness as zinc oxide. It is used with natural and synthetic rubber as an accelerator activator and inert filler, and also as a white pigment.

Use is small.

(31) Zinc sulfide is used principally in the form of lithopone, which contains about 30 percent of zinc sulfide with barium sulfate; it is also used as pure zinc sulfide in natural and synthetic rubbers and latices as a white pigment. Purity and fineness should be the same as for zinc oxide.

Use is small.

(32) Zinc yellow (zinc chromate) is made by treating zinc sulfate, chloride, or other soluble salts in water solution with sodium di-chromate. Zinc yellow is made in various shades. The same degree of purity and fineness as for zinc oxide is needed. Zinc yellow is used as a bright yellow pigment in natural and synthetic rubbers.

Use is small.

DIVISION OF MINES PUBLICATIONS ISSUED MAY 1, 1949 TO OCTOBER 1, 1949

BULLETINS

118. (REPRINT) Geologic formations and economic development of the oil and gas fields of California, prepared under the direction of Olaf P. Jenkins. 1943. 773 pp., 6 pls., 1 map, 81 index maps, 296 figs. Price $6.00.

Contains: Part 1, Development of the Industry; Part 2, Geology of California and the occurrence of oil and gas; Part 3, Descriptions of individual oil and gas fields; Part 4, Glossaries, bibliography, and index; Outline geologic map of California showing oil and gas fields and drilled areas (Economic mineral map of California no. 2—Oil and gas), scale 1:1,000,000.

123. (REPRINT) American mining law, with forms and precedents, by by A. H. Ricketts. 1943. Vol. 1, pp. i-xxxi, 1-618; vol. 2, pp. 619-1018. Price $3.00.

142. The counties of California—mineral resources and mineral production. 1949. 197 pp., 1 fig., 12 pls., 54 tables. Price, paper-bound $1.25; cloth-bound, $2.00.

(California residents please add 3% sales tax.)

CALIFORNIA JOURNAL OF MINES AND GEOLOGY

Vol. 45, no. 3, July 1949, pp. 359-502, pls. 19-23, 3 figs. *Price 75¢.*

Contains: Water-flooding as a method of increasing California oil production (Part 2, A survey of California conditions relative to the application of water-flooding), by Wilbur H. Somerton, pp. 363-416; Mines and mineral resources of Butte County, California, by J. C. O'Brien, pp. 417-454, pls. 19-23; Roofing granules in the southwest, by Stuart H. Ingram, pp. 455-458; The western pulp and paper industry as a consumer of chemicals, by R. G. Mispley, pp. 459-464; Mining law in recent years, by William E. Colby, pp. 465-490; Ione-Carbondale clays, Amador County, California, by F. T. Johnson and Spangler Ricker, pp. 491-498, 3 figs.; Address of Governor Earl Warren to the American Institute of Mining and Metallurgical Engineers, Inc., pp. 499-502.

The following is included with report, or may be purchased separately: Map of Butte County, showing location of mines and prospects, scale 1" = 3 mi.; price 25¢.

INDEX TO VOLUME 45*

Chapter 1, January 1949, includes pp. 1-116
Chapter 2, April 1949, includes pp. 117-358.
Chapter 3, July 1949, includes pp. 359-502.
Chapter 4, October 1949, includes pp. 503-590; Supplement, 115 pp.

Consolidated Table of Contents

Atomic Energy, An Act for the Development and Control of, 335-356
Barium, 85-97
Butte County, Mines and Mineral Resources, 417-454, pls. 19-23
California Division of Mines, Annual Report, 99th Fiscal Year, 7-29; publications issued September 1, 1948 to November 30, 1948, 107; September 1, 1948 to February 15, 1949, 357-358; May 1, 1949 to October 1, 1949, 562
Elephant as They Saw It, The—a collection of contemporary pictures and statements on gold mining in California: Centennial supplement to the California Journal of Mines and Geology for October 1949—115 pp.
Kern County, Mineral Resources, 203-297, pls. 9-18
Limestone near Gazelle, Siskiyou County, Geology of, 514-520, pl. 26
Limestone near Sonora, Tuolumne County, Geology of, 509-513, pls. 24, 25
Limestone and Dolomite, Industrial Uses of, 319-334
Minerals of California—Supplement No. 1 to Bulletin 136, 521-540
Mining Law in Recent Years, 465-490
Penn Mine Slag Dump and Mine Water, Calaveras County, 99-105
Pulp and Paper Industry, Western, as a Consumer of Chemicals, 459-464
Quicksilver Deposits of the Oakville District, Napa County, 31-46, pls. 1-3
Roofing Granules in the Southwest, 455-458
Rubber Industry, Materials of Inorganic Mineral Origin Used in, 553-561
State Geological Surveys, 299-317
Tuolumne County, Mines and Mineral Resources, 47-83, pls. 4-8
U. S. Geological Survey, Map Symbols Used in Publication of, 109-116
Warren, Governor Earl—Address to American Institute of Mining and Metallurgical Engineers, 499-500
Water-Flooding as a Method of Increasing California Oil Production: Part 1, 123-202; Part 2, 363-416; Part 3, 541-551

Index

A

Adams, W., gold, Kern County, 261
Ajax gold claim, Kern County—see Karma, 227, 262
Alabama Geological Survey, 302
Alabama gold mine, Tuolumne County, 56-57
Alameda gold mine, Tuolumne County, 57
Albertson, Geo. and C. E., gold, Kern County, 261
Albion Cons. gold group, Tuolumne County, 57
Alice antimony mine, Kern County, 206, 252
Aliso Canyon oil field, characteristics, 371, 386, 401
Alkali, limestone for manufacture of, 327-328
Alladin gold mine, Butte County—see Shawnee, 430, 451
Allen, L. M., tungsten, Kern County, 273
Allingham, E. F., copper-zinc, Butte County, 421, 425-426, 440
Alm, Gilbert, gravel, Butte County, 435-436, 441
Alondra oil field, characteristics, 371, 386, 401
Alpine County mineral occurrences: halotrichite, 526; melanterite, 528; romerite, 531
Alta mercury claim, Napa County—see La Joya mine, 39
Alum, use in paper manufacture, 462
Alunite, Sonoma County deposit, 522
Alunogen, Sonoma County deposit, 522
Alvarado gold placer, Butte County, 440
Amador County: chromite occurrence, 524; Ione-Carbondale district clays, 491-498
Amalia antimony mine, Kern County, 206-207, 252
Amalie gold mine, Kern County, 253

---

* Prepared by Beth Collins.
Page numbers preceded by "S" refer to supplement to the October Journal.

Amargo bentonite deposit, Kern County, 245, 276
Amario gold mine, Tuolumne County—see Junction, 68-69
Amend, August—gold, Butte County, 449
American gold mine, Kern County—see Pine Tree, 265
  gold placer, Butte County, 440
  Golden Eagle gold mine, Kern County, 253
  Inst. Min. and Met. Eng., San Francisco meeting, 500-502; address of Governor Earl Warren to, 499-500
  Mineral Co., clay, Kern County, 246, 277
Amphiboles, California deposits, 522
Amy gold mines group, Kern County, 210, 253
Analcime, Los Angeles County deposit, 522
Anatase, Riverside County deposit, 522
Ancher (Ancker), Albert—gold, Kern County, 214-215, 253, 255
Anderson & Amberg gold claim, Tuolumne County, 58
Anderson, H. J., gold, Butte County, 440, 446, 449
Anita No. 1 scheelite claim, Tuolumne County, 82
Ant Hill oil field, Kern County: characteristics, 379, 394, 409; production 1940-47, 287
Antelope Hills oil field, Kern County: characteristics, 379, 394, 409; production 1940-47, 88
Antelope Materials Co., clay, Kern County, 245, 277
Antelope Valley marble quarry, Kern County, 278
Antimony Cons. Mines, Kern County, 252
  , Kern County, 206-207, 252
  Mines Co., Kern County, 206-207, 252
  Peak antimony mine, Kern County, 207, 252
Antrm, Frank, gold, Butte County, 443
Apache copper-gold-silver mine, Kern County, 208, 253
App, Dutch, Heslep and Hitchcock gold mines, Tuolumne County, 58
Aragonite, Monterey County deposit, 522
Arants, Jess, gold, Kern County, 256
Arizona Bureau of Mines, 302
Arizona gold claim, Kern County—see Valley View, 236, 269
Arkansas Division of Geology, 302-303
Arkose in oil reservoir sandstones, 135
Arroyo Grande oil field, characteristics, 378, 392, 408
Arsenic, Kern County deposits, 207, 252
Asbestine, use in rubber industry materials, 555
Asbestos: Butte County, 421; Tuolumne County, 48-49
Asher, Arthur—Antimony Cons. Mines, Kern County, 252
Ashley, Lloyd, asbestos, Tuolumne County, 48-49
Atkinson, T. W., Estate, gold, Kern County, 268
Atlas gold mine, Tuolumne County, 58-59
Atomic Energy Act of 1946, 335-336: appropriations, 356; atomic energy utilization, 344-345; authority, general, 351-353; definitions in, 355-356; enforcement, 354-355; fissionable materials production, 338-340; information control, 346-349; international arrangements, 345-346; Joint Committee on Atomic Energy, 354; Judicial review and administrative procedure, 353; materials control, 340-343; military applications of atomic energy, 344; organization, 336-338; patents and inventions, 349-351; policy declaration, 355; property of the Commission, 346; property, private, compensation for, 353; reports to Congress, 355; research, 338; separability of provisions, 356
Aurichalcite, Inyo County deposit, 522
Axinite, Inyo County deposit, 522

B

Bacigalupi gold mine, Tuolumne County—see Baker Ranch, 59
Bacon Hills area, Kern County, oil production 1940-47, 289
Bader Bros. gold deposit, Butte County, 440
Baker borax mine, Kern County, 242-244; diagrammatic plan and section, 242
Baker Ranch gold mine, Tuolumne County, 59
Bald Eagle tungsten deposit, Kern County, 271
Bald Mountain tungsten mine, Kern County, 272
Ball, Chas., gold, Kern County, 259
Baltic gold mine, Kern County, 253
Banner gold mine, Butte County, 440
Barbarossa gold mine, Kern County, 253
Bardsdale Area oil field, characteristics, 376, 391, 406
Bardshaw, H. P., Estate, gold, Kern County, 223, 260
Barite, 87: marketing in the United States, 93-94; preparation for market, 91-92; San Luis Obispo County deposit, 522; use in rubber industry materials, 555

Barium, 85-97: bibliography, 96-97; compounds, 85-86; compounds preparation, 92-93; deposits, location, 88-90; history, 95-96; mode of occurrence, 88; ores, 87; properties, 85; prospecting and mining methods, 90-91; tests for, 87-88; uses, 94-95
Barnett gold mine, Kern County, 253
Barnsdall Oil Co., Kern County, 286
Barton, C. V., gold, Butte County, 428
Bartram, H., gold, Butte County, 452
Basin View tungsten mine, Kern County, 240-272
Bean, Albion H. and Lash—gold, Butte County, 449
Beauregard Extension gold mine, Kern County, 210, 254
  gold mine, Kern County—see also Big Blue, 253
Bedding, map symbols used by the U. S. Geological Survey, 112
Beehive gold mine, Kern County, 254
Beehive lead-silver property, Kern County, 270
Beek, Margaret J., gold, Butte County, 447
Beerman & Jones, stone quarry, Tuolumne County, 82
Bell Columbia marble quarry, Tuolumne County, 76-77
Bella Oak mercury mine, Napa County, 43-46: geologic map, pl. 3; geology, 44-46; history, 43-44; suggestions for further exploration, 46
Bella Union mercury mine, Napa county—see Bella Oak, 43
Belridge oil fields, North and South, Kern County: charactristics, 379-380, 394-395, 409-410; production 1940-47, 288
Ben Hur gold mine, Kern County—see Sailor Boy, 267
  tungsten, Kern County—see Gold Wash, 273
Bender Oil Operations, Kern County, 286
Benitoite, San Benito County deposit, 523
Benko, George and Shay & Miller Estates, gold, Kern County, 212-213, 254
Bennett, G. E., gold, Kern County, 266
Berry Creek gold property, Butte County, 440
Beryl gold mines group, Kern County, 210-211, 254
Beverly Hills oil field, characteristics, 371, 386, 401
Bibliography: barium, 96-97; minerals of California, 534-535; Tuolumne County mines and mineral resources, 83; water-flooding to increase oil production, 200-202
Bicknell gold mine, Tuolumne County, 59
Bidsworth, William, gold, Butte County, 447
Bidwell, John: On the discovery of gold in California, 1841, S19; On the discovery of gold, January 1848, S39-40; On exploration for gold in California, 1844-45, S15
Big Bend copper-zinc mine, Butte County, 421, 425-426, 440
  Blue gold mine, Kern County, 211-212, 254; see also Nellie Dent, 264
  Dyke gold mine, Kern County, 212-213, 254
  Gold mine, Kern County, 213, 254
  Joe gold mine, Butte County, 440
  Lode tungsten mine, Kern County, 272
  Tungsten mine, Kern County, 272
Bigler, Henry W., discovery of gold January 24, 1848, as recorded in diary of, S31
Bingstresser gold mine, Butte County, 440
Bishop, Jack, gold, Kern County, 217, 256
  , Mrs. J. S. (Josie), Kern County mines: beryl, 210-211; bentonite, 276; gold, 210-211, 254, 260, 266; and H. H., and Cook, H. D., copper, 208-209, 253
Bissell magnesite deposit, Kern County, 279
Bix Butte Mining Co., gold, Butte County, 442
Black Diamond gold mine, Butte County, 432
  , Dora M. and LeRoy E.—ochre, Butte County, 434, 449
  Eagle and Grey Eagle perlite deposits, Kern County, 249, 279
  Hawk gold mine: Kern County, 214, 254: Tuolumne County, 59
    lead-zinc group, Kern County, 238, 270
    Plumbago placer mine, Tuolumne County—see Morgan graphite, 75
  Jack and Ida Della gold claims, Tuolumne County, 60
  Leg Creek, Tuolumne County, geologic map and structure of limestone deposits, pl. 24
  Mountain gold mine, Kern County, 254
  Mountain pumice mine, Kern County, 249, 279
Blackwell's Corner oil field, characteristics, 380, 395, 410
Blanc fixe, use in rubber industry materials, 555-556
Bloomer Hill gold mine, Butte County, 440
Bloomington gold mine, Butte County, 440
Blue Eagle gold-silver mine, Kern County—see Cactus Queen, 216-217, 255
  Hog gold mine, Butte County, 441
  Jay gold mine, Kern County, 214, 254
  Mountain Mining Co., gold, Kern County, 255
  Point tungsten mine, Kern County, 272

Boehmite, Riverside County deposit, 523
Bolton, C. V., gold, Butte County, 446
Bonanza gold mine, Tuolumne County, 60
King lead mine, Butte County, 441
King lead-silver prospect, Butte County, 433
Bond Buyer gold-silver-copper group, Kern County, 255
Bonham, Charles, sand and gravel, Butte County, 435-437, 441
Borates, Kern County, 241, 243-244
Bordoli, G., and Brothers, limestone and marble quarry, Tuolumne County, 77
Bornite, Siskiyou County deposit, 523
Boston gold quartz mine, Butte county, 441
Borthwick, J. D., "Sees the elephant," S63-78
Boussingaultite, Sonoma County deposit, 523
Bowerbank gas field, Kern County, production 1940-47, 297
Bowles, Oliver, and Jensen, Nan C., *Industrial uses of limestone and dolomite*, 319-334
Bowman gold mine, Kern County, 214, 255
Boyd, Richard, and Dimoush, Leonard, gold, Kern County, 210, 254
Braden, E. A., gold, Kern County, 269
Bradshaw, H. P., Estate, gold, Kern County, 223, 260
Brea-Olinda oil field, characteristics, 371, 386, 401
Brewer, Chas., gold, Kern County, 254
Bright Star gold mine, Kern County (two), 255
British-American and Capital Co., Kern County, 287
Brookite, Kern County deposit, 523
Brown, R. A. (and others), tungsten, Kern County, 273
Brucite, Riverside County deposit, 523
Bryan gold mine, Kern County, 255
Buchanan gold mine, Tuolumne County, 60
Buckboard gold mine, Kern County, 255
Buckeye gold group, Tuolumne County, 61
Buckhorn tungsten mine, Kern County, 272
Buena Vista Lake oil field, Kern County—see Paloma, 295
Bull Run gold mine, Kern County—see also Big Blue, 255
Bully Boy gold mine, Kern County, 255
Burch, Chas., gold, Kern County, 259
Bureau of Land Management, Federal, 468-469
Burning Moscow gold mine, Kern County, 215, 255
Burroughs, Chas. S., et al., gold, Butte County, 446
Burton, Brite, and Blank gold mine, Kern County, 215-216, 255
Burton gold properties, Kern County, 234-235, 263, 265, 269
Burtz Placer Mining Co., gold, Butte County, 441
Butte County, geography, 418
, geology, 419-420
gravel plant, 435, 441; photo, pl. 19A
, map showing mines and mineral deposits, pl. 23
, mineral production statistics 1880-1946, table showing, 422
, mines and mineral resources, 417-454, pls. 19-23
, mines and minerals, 420-454
, mines, tabulated list, 440-454
, topography and climate, 418-419
, transportation, 419
Butte Creek Rock Co., Butte County, 435-436, 441; sand and gravel plant photo, pl. 19B
Butte Lode Mining Co., gold, Kern County, 216, 255
Butte Wedge gold mine, Kern County—see Cons. Mines, 256
Buttebred, H., and Stover, L. V., tungsten, Kern County, 274
Butterfly gold mine, Butte County—see Morris Ravine, 449
Buttonwillow gas field, Kern County, production 1940-47, 297

C

Cactus Mines Co., gold-silver, Kern County, 216-217, 255
Cactus Queen gold-silver mine, Kern County, 216-217, 255
Cadillac tungsten mine, Kern County, 272
Cadmium yellow, use in rubber industry materials, 556
Calaveras County: chromite occurrence, 524; garnet occurrence, 525; Penn copper mine, slag dump and mine water, 99-105; penninite occurrence,
Calcite, Tulare County deposit, 523
Calcium carbide, limestone used in production of, 329-330
Calcium carbonate: ground, use in rubber industry materials, 556-557; precipitated, 556
Calcium silicate, precipitated, use in rubber industry materials, 557
Caldwell gold mine, Kern County, 256

California Engels Mining Co., gold, Kern County, 258
  fuller's earth, Kern County, 277
  minerals, Supplement No. 1 to Bulletin 136, 521-540
  oil fields, characteristics, 367-370
  oil production, water-flooding as method of increasing, 123-202, 363-416, 541-551
  State Division of Mines, Dept. Natural Resources, 303; annual report, 7-29
Californite, Butte County, 426
Calsico Corp., volcanic ash, Kern County, 250, 279
Cambrian dolomite, barium occurrence in, 88
Campbell, Geo. L., gold, Butte County, 447
  , Joe S., gold placer, Butte County—see Steiffer, 452
Canal oil field, Kern County: characteristics, 380, 395, 410; production 1940-47, 293
Canfield Ranch oil field, Kern County production 1940-47, 295
Cannon, Dr. Frank M., gold, Butte County, 441
Capillary and surface effects in water-flooding oil wells, 171-174; dynamic aspects, 173-174; importance of, 174; static conditions, 171-172
Capitan oil field, characteristics, 378, 393, 408
Carlisle gold mine, Butte County, 441
Carr, Geo., gold, Kern County, 267
Casey, Hiram E., gold, Kern County, 258
Casmalia oil field, characteristics, 378, 393, 408
Cassiterite, Kern County deposit, 523
Castle, Lemuel L., gold, Butte County, 445
Cat Canyon oil field, characteristics, 378, 393, 408
Caustic soda, use in pulping process, 462
Celestite, description, 87; San Bernardino County deposit, 523
Cement production, Kern County, 244-245
Cementing materials in oil reservoir sands, influence on water-flooding, 142-143
Central gold mine, Butte County, 441
  sand and gravel plant, Butte County, 436-437, 441; photo, pl. 19C
  Valley floor oil fields, Kern County, production, 1940-47, 292-295
Chamberlain, P. C., gold, Kern County, 217, 226-227, 256, 262
Channel Mining Co., gold, Butte County, 426, 441
Chapman zone, Richfield oil field, water-flooding experiment, 364-365
Chemicals, pulp and paper industry as consumer of, 459-464; table showing approximate annual consumption, 461
  , table showing annual U. S. limestone production and use, 320-324
  used for primary pulp production, 460-462
  used in paper industry, sizing materials, 462
Cherokee Flat Blue Gravel gold mine, Butte County, 441
Chief gold mine, Kern County, 256
Childress Ranch, limestone and marble, Tuolumne County, 77
China clay, use in rubber industry matrials, 557
Chinese Gravels, Inc., Tuolumne County, 74
Chino area oil field, characteristics, 371, 386, 401
Chlorine, use in pulping process, 462
Chlorite, Calaveras and Tehama County deposits, 523
Chondrodite, Riverside County deposit, 524
Chromite, Butte County, 421
  , California deposits, 524
  , Tuolumne County, 49, 52-53
Church Lode patented land, Butte County, 442
Churchill lead-silver mine, Kern County, 271
Cinnabar, California deposits, 524
Clapp, George H., gold, Kern County, 214, 254
Claraville gold placers, Kern County, 256
Clark, J. B., pocket gold, Tuolumne County, 72
Clark & Stent, gold, Butte County, 454
Claussenius, C. H., gold, Kern County, 265
Clay, Butte County, 421
  content in oil reservoir sands, effect on water-flooding, 548; influence on the "mobility ratio," 548-549; water treatment to control swelling, 549
  , Kern County, 245-246
  minerals in reservoir sands, table showing tentative classification, 138
  , use as pigment in paper manufacture, 463
  , use in rubber industry materials, 557
Clays in oil reservoir sands, influence on water-flooding, 138-142
  , Ione, cross sections of portion of, 494, 496
  , Ione-Carbondale district, Amador County, 491-498; analysis typical core, 497; assay of chip, core, channel, and sludge samples, table showing, 498; description, 495, 497; history, 493; map showing portion of, 492; method of sampling, 498; ownership, 495; physical features, 493, 495; U. S. Bureau of Mines exploration of, 497

Cleveland, Norman, gold, Kern County, 266
Climate and topography, Butte County, 418-419
Clinozoisite, Sonoma County deposit, 524
Cloudman, Erin-go-bragh and—patented gold mines, Tuolumne County, 64-65
Coal, Butte County, 421
Coal-mine dusting, limestone used for, 332-333
Coalinga Extension oil field, characteristics, 384, 399, 414
Coalinga oil fields group, characteristics, 384, 399, 414
Cohn, Bertha M., gold, Butte County, 447, 451
Colby, William E., *Mining law in recent years*, 465-489
Coles Levee oil fields, North and South, Kern County: characteristics, 380, 395, 410; production 1940-47, 293
Collar Button gold mine, Kern County, 256
Colorado Geological Survey, 303
Columbia mercury claim, Napa County—see La Joya Mine, 39
  Marble Co. quarry, Tuolumne County, 77; photo, pl. 6B
Columbus gold mine, Tuolumne County, 61
Comanche mercury claim, Napa County—see La Joya Mine, 39
Comanche Point area, Kern County, oil production 1940-47, 296
Commonwealth gold mine, Kern County—see Big Blue, 211-212, 254
Confidence gold mine, Tuolumne County, 61-62
Confidence gold mines group, Kern County, 256
Congress, report of Atomic Energy Commission to, 344-345, 355
Connate water in petroleum reservoirs: importance in water-flooding, 155-156; means of determining content, 165-166
Connecticut Geological and Natural History Survey, 303
Consolidated Mines Co., gold-tungsten, Kern County, 256, 259, 272
Contact arsenic mine, Kern County, 207, 252
Contacts, map symbols used by U. S. Geological Survey, 110
Content gold mine, Kern County, 256
Contention gold placer, Butte County, 442
Continental Oil Co., Kern County, 292
Contra Costa County, diallage occurrence, 530
Copiapite, Lake County deposit, 524
Copper Basin copper group, Kern County, 208, 253
  , Kern County deposits, 208-209, 253
  , Tehama County deposit, 524
  , Tuolumne County, 53-54
  -zinc, Butte County, 421, 425-426, 440
Copperola copper mines group, Kern County, 208, 253
Core analysis in petroleum reservoirs for saturation determination, 163-164
Cortes, Hernando, to Charles V, Holy Roman Emperor and King of Spain, 1524, S10
Cory & Strong, gold placer, Butte County, 442
Cottonwood Creek gypsum deposit, Kern County, 247, 278
Coughran, Eliza, and Canfield, Mary—tungsten, Kern County, 272
  , R. L. and Alice—antimony, Kern County, 206, 252
Coulston, Mrs. Nora D., gold, Kern County, 266
Coulston Estate, gold, Kern County, 261
Covellite, Siskiyou County deposit, 524
Cow Canyon tungsten mine, Kern County, 272
Coyote oil fields, East and West, characteristics, 371, 386, 401
Cram, A. L., gold placers, Kern County, 268
Cretaceous, Oakville district, Napa County, 35
Criss Cross and Relief patented lode claims, Tuolumne County, 62
Cristobalite, Riverside County deposit, 525
Croesus gold placers group, Kern County, 217, 256
Crown Point gold mine, Butte County, 442
Crystal Gypsum Co., Kern County, 247, 278
Crystal Springs gold placer, Tuolumne County, 62
Cudahy Packing Co., volcanic ash, Kern County, 279; photo, pl. 13A
Cuddeback Cinnabar Corp., mercury, Kern County, 271
Cuddeback, J. C. (and others), tungsten, Kern County, 273
Cuddy Canyon limestone deposit, Kern County, 278
Cuddy, Florence, dolomite, Kern County, 278
Cuddy, R. C., asbestos, Kern County, 276
Cully and Hoyes tungsten mine, Kern County—see Tejon Ranch Co., 276
Cunningham, W. T., gold, Kern County, 217-218, 256
Curtisite, Lake County deposit, 525
Cymric oil fields group, characteristics, 380-381, 395, 410-411
Crytolite, Riverside County deposit, 525

D

Dailey Chemical Laboratories, gold, Butte County, 426-427
Dakin Co., gold, Butte County, 453

Daley, H. W., and Munson, Geo., tungsten, Kern County, 275
Dally gold mine, Butte County—see Channel, 426, 441
Daly, A. D., gypsum, Kern County, 248-249, 278
Darnell, J. A., lead-zinc, Kern County, 238, 270
David King gold mines group, Kern County, 256
Davis, Jeff, Lady Belle-, gold group, Kern County—see Big Blue, 211-212, 254
Davis, William Heath, On gold in the Sacramento Valley, 1843-44, S14
Dead River gold placer, Kern County, 256
Dead Tree gold mine, Kern County, 257
Dearborn gold mine, Kern County, 257
Deer Hunter gold mine, Kern County, 257
Del Valle oil field, characteristics, 372, 387, 402
Delano Paint claim, Butte County, 442
Dell, Hazel, gold placer, Butte County, 444
DeMayo, A., gold, Kern County, 258, 270
Denman, Wm., gold, Butte County, 441
Densmore gold mine, Tuolumne County, 62-63 ; photo, pl. 4
Densmore, Mary M., and Wallace—gold, Butte County, 440
Dent, Nellie, gold mine, Kern County, 264
Desert Queen mines, Kern County—see Exposed Treasure and, 218, 258
Devil's Den oil field, Kern County : characteristics, 381, 396, 411 ; production 1940-47, 288
Dewey gold lode, Butte County, 442
Diallage, Contra Costa County deposit—see pyroxenes, 530
Diamond Match Co., gold, Butte County, 430, 451
Diamond Cherokee gold mine, Butte County—see Diamond Placer No. 1, 442
Diamond Placer No. 1, gold, Butte County, 442
Diamonds, Butte County, 426
Diatomaceous silica, use in rubber industry materials, 557-558
Dinsmore, Mary M. and Wallace—gold, Butte County, 446
Diopside, Riverside County deposit—see pyroxenes, 530
Disinfectants, limestone in preparation of, 333
Dix drift gold mine, Butte County, 442
Doble, Edward, gold, Kern County, 269
Dodgson, Ruth, gold, Butte County, 442
Dodsworth, R. E., gold, Kern County, 261
Dolomite and limestone, industrial uses, 319-334
Domenghini, Dominic, gold, Kern County, 255
Dominguez oil field : characteristics, 372, 387, 402 ; water-flooding project, 365
Dondero, Raymond and Clarence—gold, Tuolumne County, 73
Donlevy tungsten mine, Kern County, 240-241, 272
Donnie gold mine, Kern County, 218, 257
Dorothy Lake scheelite prospect, Tuolumne County, 82
Dorris and Cuddeback, tungsten, Kern County, 275
Dosie, Juan—gold, Kern County, 262
Dosworth, R. E., gold, Kern County, 261
Double Standard gold mine, Kern County, 257
Dreadnot gold mine, Kern County—see Blue Mountain, 255
Dresser, D. M., gold, Kern County, 256
Drunkard's Dream gold mine, Kern County, 257
Dumortierite, Riverside County deposit, 525
Dungan, Edyth, and Ford, A. W.—gold, Butte County, 441, 448, 449
Dunkley, Dorothy M. : gold, Butte County, 443, 444 ; and Ogburn, Betty M., gold, Butte County, 454
Dunning Ranch, limestone and marble, Tuolumne County, 77
Duran, J. R., bentonite, Kern County, 277
Dutch Cleanser volcanic ash, Kern County—see Cudahy silica, 279
Dutch gold mine—see App et al., Tuolumne County, 58
Dyestuffs, use in paper manufacture, 463

E

Eagle mercury claim, Napa County—see La Joya, 39
Eagle Shawmut gold mine, Tuolumne County, 63-64 ; photo of mill, pl. 5B
East Belt, Mother Lode, Tuolumne County, 55-56
East Los Angeles oil field, characteristics, 372, 387, 402
East Side oil fields, Kern County, development and production 1940-47, 283-288
Echo, Elephant, Gray Eagle, gold mine, Kern County, 257
Eclipse silver-gold group, Kern County—see Gold Cross and Standard, 219, 258
Economics of water-flooding oil reservoirs, 195-199 ; physical factors, 197-198 ; price, supply, and demand, 198 ; summary, 199
Edel Mining Co., gold, Butte County, 452
Ederl Mines, Ltd., gold group, Kern County, 257
Edison oil field, Kern County : characteristics, 381, 396, 411 ; production 1940-47, 287 ; photo, pl. 12B

Edith silver-gold group, Kern County—see Gold Cross and Standard, 219, 258
Egenhoff, Elisabeth L., *The elephant as they saw it—a collection of contemporary pictures and statements on gold mining in California*, 115 pp. (Centennial supplement to the California Journal of Mines and Geology for October 1949)
Eisenman, Walter C., perlite, Kern County, 249
El Diablo Mining Co., tungsten, Kern County, 272
  Dorado Limestone Co., gold, Butte County, 454
  Monte gold mine, Butte County, 442
  Paso Mountains, Opal pumice, photo, pl. 9
  Segundo oil field, characteristics, 372, 387, 402
Elbow and Boulder gold placer, Kern County, 257
Elbow gold placer, Butte County, 442
Electrical logs, saturation of reservoir formation from, 166-167
Electrical models of fluid flow in oil reservoirs, 180-182
Elephant as they saw it, The—a collection of contemporary pictures and statements on gold mining in California, as a centennial supplement to the California Journal of Mines and Geology for October 1949, 115 pp.
Elephant gold mine, Kern County—see Echo, Elephant, Gray Eagle, 257
Elk Hills oil field, Kern County: characteristics, 381, 396, 411; production 1940-47, 292
Elliot, M. D., gold, Kern County, 257
Ellston, R. E., gold, Kern County, 257
Elwood oil field, characteristics, 378, 393, 408
Embolite, San Bernardino County deposit, 525
Emma gold mine, Butte County, 443
Emma No. 2 gold placer, Butte County, 443
Engler Lime Co., Tuolumne County, 77
Epsomite, Lake and Sonoma County deposits, 525
Equipment Sales Co., marble quarry, Tuolumne County, 76
Equitable gold mine, Butte County, 443
Erdman, P., gold, Kern County, 269
Erin-go-bragh and Cloudman patented mines, Tuolumne County, 64-65
Erricart gold mines group, Kern County, 210, 262
Erskine Creek limestone deposit, Kern County, 278
Esperanza gold mine, Kern County, 257
Ethel gold mine, Butte County, 443
Eureka gold mine, Kern County, 218, 257
Eureka and Grizzly gold lode claims, Tuolumne County, 65
Eureka Plumbago graphite mine, Tuolumne County, 75
Evening Star copper-zinc mine, Butte County—see Big Bend, 421, 425-426, 440
Experimental gold mine, Tuolumne County, 65-66
Exposed Treasure and Desert Queen gold mines, Kern County, 218, 258
Exposition 1915, No. 1 gold mine, Butte County, 443
Extension Ajax gold mine, Kern County—see Monarch, 230, 264

F

Faults, map symbols used by U. S. Geological Survey, 110-111
Fayette & La Shalle gold mine, Butte County, 443
Feather River Land & Mining Co., gold, Butte County, 441
Federal Land Department, now Bureau of Land Management, 468-469
Feehan, John A. and Frank X—gold, Butte County, 445, 447
Feldman, Frank, tungsten, Kern County, 272
Feldspar, Kern County deposits, 246-247, 278
Fergusin, D. (?), gold, Kern County, 264
Ferris gold mine, Kern County, 258
Fertilizer filler, limestone used as, 331
Fidgie tungsten group, Kern County, 273
Fifty-five gold mine, Tuolumne County, 66
Filtrol Corp. clay, Kern County, 245-246, 277
Financial statement, California Division of Mines, 9
Fine Gold gold placer, Kern County, 258
Firestone Tire & Rubber Co., Materials of inorganic mineral origin used in the rubber industry, 553-561
Fissionable materials, Atomic Energy Act of 1946: control of, 340-341; production of, 338-340
Fix, Philip F., and Swinney, C. Melvin—*Quicksilver deposits of the Oakville district, Napa County, California*, 31-46, pls. 1-3
Florida Geological Survey, 303-304

Fluid displacement in petroleum reservoirs: from individual pores, 176-177; from sand bodies, 175-176; principles of, 174-177
    flow in oil reservoirs: mathematical analysis, 177-179; model studies, 179-182; principles of, 177-182; summary, 182
    flow and recovery characteristics in petroleum reservoirs, influence of saturation on, 168-170
    saturation in petroleum reservoirs, 162-171: core analysis for determining, 163-164; from electrical logs, 166; influence on flow and recovery characteristics, 168-170; necessary to calculations of total and recoverable oil, 167-168; restored-state method for determining, 165-166; summary and correlation to California conditions, 170-171
Fluids in petroleum reservoirs: correlation to California conditions, 162; distribution and nature, 151-162; modes of occurrence, 151-152; oil phase, 152-155; water phases, 155-161
Fluming, use in gold mining 1848-57, S93-95
F. O. B. tungsten mine, Kern County, 273
Foisse, J. A., lead-silver, Kern County, 271
Folds, Map symbols used by U. S. Geological Survey, 111-112
Foliation and cleavage, map symbols used by U. S. Geological Survey, 113
Folsom, Joseph L., On Marshall's first flake of gold, August 23, 1848, S49
Forbestown Cons., gold, Butte County—see Gold Bank, 443
Four Deer oil field, characteristics, 378, 393, 408
Four Jacks gold mine, Kern County, 258
Four K tungsten group, Kern County, 273
Fowler, W. D., gypsum, Kern County, 278
Franceshi, N. V., gold-tungsten, Kern County, 228, 263
Franklin gold mine, Tuolumne County—see O'Hara, 70
French Meadows gold mine, Kern County—see Bowman, 214, 255
French, William, copper-gold-silver group, Kern County, 253
Fresno County, scheelite occurrence, 531
Fruitvale oil field, Kern County: characteristics, 381, 396, 411; production 1940-47, 287
Fulron, A. D., gold, Kern County, 256
Fungicides, limestone in preparation of, 333
Furlong, Herbert W., gold, Butte County, 446

G

Galvin, Helene, gold mine, Kern County, 260
Garnet, California deposits, 525
Garrette, J. F., gold, Butte County, 440
Gas (dry) fields, Kern County, oil production 1940-47, 296-297
Gaumer, J. A. (J. O.?), and Miles, Alice—gold, Butte County, 446, 449
G. B. gold mine, Kern County, 258
Gehlenite, Inyo County deposit, 526
Giekielite, Riverside County deposit, 526
Gem gold mine, Kern County, 258
Gems, Butte County, 426
General Petroleum Corp., Kern County, 291
Genii Mining Co. Lease, gold, Butte County, 443
Geography: Butte County, 418; Oakville district, 33; Tuolumne County mining areas, 48
Geologic conditions influencing water-flooding oil reservoirs, 129-132; in California, 131-132
    formation and zone names used in Kern County report, 285
    investigations, California cooperative, 22-24
    map—Bella Oak mine, Napa County, pl. 3; La Joya mine, Napa County, pl. 1
    mapping, basic—California Division of Mines, 21-22
    occurrence of oil, Kern County, 283
    structure—Oakville district, 37; of oil wells, influence on water-flooding, 129
Geological and mineralogical characteristics, California oil fields, 369-370, 386-400
    survey work: financial aspect, 302; training of men in, 301
    Surveys—federal and state cooperation, 300; state, 299-317, scope and activities, 300
Geology, barium occurrence, 88
    , Butte County, 419-420
    , California cooperative investigations in, 22-24
    , limestone near Gazelle, 514-520; near Sonora, 509-513
    , Oakville district, 34-37
George, Ed: gold, Kern County, 234, 268; and Erricart, Martin J.—gold, 210, 253
George Mullins Co., Tuolumne County dredging operations, 74
George, William, gold lode, Butte County, 454
Georgia Department of Mines, Mining, and Geology, 304
Gerbracht, Della: copper, Kern County, 208, 209, 253; Meuer and—perlite, 249, 279, pumice, 249, 250, 279

Geringer, J. C. (James C.), and O. G. (Otto G.), gold-tungsten, Kern County, 223-224, 257 (two), 260, 261, 273
Gibson, Charles, gold, Kern County, 256
Glass, limestone in manufacture of, 330
Glaucophane, Sonoma County deposit—see amphibole, 522
Glen Olive gold mine, Kern County, 258
Globe mercury claim, Napa County—see La Joya, 39
Gold Badger copper mines group, Kern County, 253
  Bag (Bar) gold mine, Kern County, 258
  Bank Cons. gold mine, Butte County, 443; see also Pine Grove, 450
  Bar placer mine, Kern County, 219, 258
  , Butte County, 426-433, 440-454
  Cross and Standard silver-gold groups, Kern County, 219, 258
  Crown gold mine, Kern County, 258
  Hill Dredging Co., gold, Butte County, 427-428, 444
  Hill gold mine, Kern County, 259
  King gold mine, Kern County, 259
  mining, 1849-60, S59-115
  Mountain gold mine, Butte County, 444
  Nugget gold placer, Butte County, 444
  Pass gold mine, Kern County, 259
  Peak gold mine, Kern County, 219-220, 259
  Peak Mines, Ltd., gold, Kern County, 259
  placer mining, Tuolumne County, 73-75
  quartz mines, Tuolumne County, 56-73
  quartz mining in California, 1848-57, S101-115
  Rush of 1842, S17-23; discovery of gold at Sutter's Mill, S25-57
  -silver deposits, Kern County, 209-238, 252-271
  Standard mine, Kern County, 220, 259
  State gold mines, Kern County—see Amy, 253
  , the mining of, 1849-60, S60-115
  , Tuolumne County, 54-75
  Wash tungsten mine, Kern County, 273
Golden Gate Mines, Inc., Tuolumne County, 66
    gold mine, Kern County—see Ferris, 259
    Pool gold mine, Butte County—see Jackpot, 446
    Queen gold mine, Kern County, 259; photo, pl. 14; see also Queen Esther, 266
    Queen Mining Co., gold, Kern County, 218, 220-223, 259, 267
    Summit gold placer, Butte County, 443
Goler Canyon gold placers, Kern County, 223, 259; see also Chamberlain and Janney groups, 223, 259
      Mining Co., gold, Kern County, 217
Good Flat gold mine, Butte County, 444
Good Hope gold mine, Kern County, 259
Good Luck gold mine, Kern County, 259
Goodall & Perkins gold property, Butte County, 449
Grand View gold mine, Butte County, 444
Granite, disintegration and decomposition, table showing, 134
Granite King gold mine, Kern County, 259
Grant, W. B. (?), gold, Kern County, 256
Graphite, Tuolumne County, 75
Gray Eagle gold mine, Kern County, 259; see also Elephant, 257
Gray Eagle magnesite deposit, Tuolumne County, 80-81
Gray, Gordon—gold, Kern County, 218, 258
Graywacke in oil reservoir sandstones, 133
Great Eastern gold claims group, Tuolumne County—see Albion Cons., 57
Great Unknown gold mine, Kern County—see also Beryl, 260
Greeley oil field, Kern County: characteristics, 381, 396, 411; production 1940-47, 292-293; waste-water disposal project, 365-366
Greenhorn Caves gold placer mines, Kern County, 223, 260
Greenslit, A. R. (and others), gold, Kern County, 259
Greenstone copper mine, Tuolumne County—see Mann, 53-54
Greenwalt, Kittie, gold, Butte County, 447
Grey Eagle perlite deposits, Kern County—see Black Eagle and, 249, 279
Gribble, Fred L., tungsten, Kern County, 273
Griffith, E. L., gold, Butte County, 451
Griffith, Earnest, gold, Kern County, 267
Grizzly lode claims, Eureka and—Tuolumne County, 65
Gross and Street gold mines, Tuolumne County, 66-67
Grouse gold quartz mine, Butte County, 444
Grubbs, Carleton, stone, Butte County, 435, 441
Grubstake gold placer, Kern County, 260
Gum Tree gold mine, Kern County, 260
Gusty, M. J., and Steadfield, C. G.—tungsten, Kern County, 240, 272
Gwynne gold-tungsten mine, Kern County, 223-224, 260, 273

Gwynne and Jennette, gold-tungsten, Kern County, 261
Gypsum, Inc., Kern County operations, 248
Gypsum, Kern County, 247-249, 278

H

Haeger (?), Mrs. ———, gold, Kern County, 260
Hagen, Rudolph, gold, Kern County, 267
Haggin, J. B., and Phoebe A. Hearst Estates, gold, Kern County, 226, 261
Hakluyt, Richard: On the rich isles of California, 1597, S12; On the voyage of Sir Francis Drake to New Albion, 1579, S11
Halite, San Bernardino County deposit, 526
Hall, I. R., Estate—gold, Butte County, 451
Halotrichite, Alpine and Sonoma County deposits, 526
Ham & Birney gold mine, Tuolumne County, 67-68
Hamilfield gold mine, Tuolumne County—see Ham & Birney, 67-68
Hancock Oil Co., Kern County, 287
Hanover gold mine, Kern County, 224, 260
Hard Gravel gold claim, Tuolumne County, 73
Harper, Charles, lode claims, Tuolumne County, 65
Harrington, W. O., and Hutchinson, T. C., gold, Butte County, 450
Harris gold mine, Tuolumne County—see Little Gem, 69
Hart & Jacobs gold claim, Tuolumne County—see Ham & Birney, 67-68
Harvard Gold Mining Co., Tuolumne County properties, 68; mine photo, pl. 5A
Havilah gold claim, Kern County—see Valley View. 236, 269
Hawk tungsten group, Kern County—see Sunset, 275
Helene Galvin gold mine, Kern County, 260
Hellwig, H., gold mine, Tuolumne County, 73
Helm oil field, characteristics, 384, 399, 414
Helmke, Ray, chromite, Butte County, 421, 444
Helvite, San Diego County deposit, 526
Hematite, Inyo and San Bernardino County deposits, 526
Hendy gold placer, Butte County, 445
Hennings, Don, tungsten, Kern County, 274
Hercig (Hercey), Mrs. Elizabeth J., gold, Kern County, 219, 258
Herkelrath, Edward, Kern County: gold, 229, 264; tungsten, 273
Herschel Kelso tungsten mine, Kern County, 273
Herschel tungsten mine, Kern County—see King, 273
Heslep gold mine, Tuolumne County—see App et al., 58
Hetherington, Arley I. and Gertrude M.—gold, Butte County, 445, 450, 453
Heulandite, San Diego County deposit, 526
Heyl, George R., and Walker, George W., *Geology of limestone near Gazelle, Siskiyou County, California*, 514-520; and Wiese, John H., *Geology of limestone near Sonora, Tuolumne County, California*, 509-513, pls. 24, 25
Hicks, Mary K., gold, Butte County, 451
Hidden Treasure gold mine, Tuolumne County, 68
Higgins, Martha G., gold, Butte County (two), 453
High Peak (Hi-) tungsten mine, Kern County, 241, 273, photo, pl. 13B
High Power tungsten mine, Kern County, 273
Hilen and Waycott, gold, Butte County, 453
History, Oakville district, Napa County, 33-34
History, water-flooding oil reservoirs in California, 364-367
Hitchcock gold mine, Tuolumne County—see App et al., 58
Hoefling Bros., copper-zinc, Butte County, 421, 425-426, 440; gold, 430-432, 452
Hoegee gold mine, Kern County, 260
Hogan-Mallory tin deposit, Kern County, 238-239, 271
Hogan Petroleum Co., Kern County, 287
Holland mine, Kern County—see Apache, 253
Holloway, H. M., Inc., gypsum, Kern County, 248, 278; photos, pl. 10
Holmes, Gail W., amphibole prospect, Tuolumne County, 49
Holmes, H. G., sand and gravel, Butte County, 446
Homer Bros., gold, Kern County, 253
Homestake gold property, Butte County, 445
Homestead gold lode deposit, Butte County, 445
Homestead gold quartz deposit, Butte County, 445
Honey Comb gold quartz deposit, Butte County, 445
Hooper, J. L., copper group, Kern County, 209, 253
Hooper, John, gold, Kern County, 263
Hornet gold lode, Butte County, 445
Houser, A. N., tungsten, Kern County, 272
Howe, J. C., tungsten, Kern County, 273
Howlite, Kern County deposit, 526
Hoyt, J. M., Jr., and Parma, Mrs. C. C.—tungsten, Kern County, 241, 273
Hub gold claims group, Kern County, 225, 260
Hubbard, Henry G. et al., antimony, Kern County, 252, 275
Hubbard, John D., gold, Butte County, 453

Hummer silver-gold mine, Kern County, 271
Huntington Beach oil field, characteristics, 372, 387, 402
Huntington gold mine, Kern County, 260
Hupp gold placer, Butte County, 445
Hurd, Ethel W., and Williams, Raymond—gold, Butte County, 445
Hurley, Mary, gold, Butte County, 442, 452; mineral paint, 442
Hutchings' California Magazine, Discovery of gold at Sutter's mill and early days of the gold rush, January 24, 1848 to August 17, 1848, S34-38; excerpts from Mining for gold in California, 1848-57
Hydraulic method of gold mining, 1848-57, S95

I

Iconoclast gold mine, Kern County, 261
Ida Bell gold mine, Butte County, 445
Ida Della and Black Jack quartz claims, Tuolumne County, 60
Idaho Bureau of Mines and Geology, 304
Ideal tungsten mine, Kern County—see also King, 273
Idocrase, Placer County deposit, 527
Igneous rocks, barium occurrence in, 88
Illinois and Golden Bell gold mine, Kern County, 261
Illinois Geological Survey Division, State Dept. Registration and Education, 305-306
Illite, properties important in water-flooding oil reservoirs, 139
Ilvaite, Shasta County deposit, 527
Imperial County mineral occurrences: manganite, 528; psilomelane, 530; pyrolusite, 530; sphene, 532; stilbite, 532
Independent Exploration Co., Kern County, 289, 290
Inderite, Kern County deposit, 527
Indian Queen gold mine, Kern County, 261
Indian Springs Mining Co., gold, Butte County, 445
Indian Wells tungsten group, Kern County—see Pyarin, 274
Indian Wells Valley gold mine, Kern County, 261
Indiana Division of Geology, State Dept. Conservation, 306
Industrial applications of limestone, 325-334
Industrial uses of limestone and dolomite, 319-334
Inglewood oil field, characteristics, 372, 387, 403
Ingram, Stuart H., *Roofing granules in the Southwest*, 455-458
Injection oil wells, behavior in water-flooding, 193-195
Injection rates and pressures in water-flooding oil reservoirs, 182-187
Injection water in petroleum reservoirs, importance of source to water-flooding, 156-157
Insecticides, fungicides, and disinfectants—limestone in preparation of, 333
Inskip gold mine, Butte County, 445
Intention Junction gold claim, Kern County—see Karma, 227, 262
Inyo County mineral occurrences: aurichalcite, 522; axisite, 522; cinnabar, 524; gehlenite, 526; hematite, 526; phyromorphite, 530; pyrophyllite, 530; scapolite, 531; scheelite, 531; sphene, 532; spinel, 532; vivianite, 534
Ione, Amador County, climatology table, 495
Ione-Carbondale district clays, Amador County, 491-498
Ione clay deposits, Amador County, cross sections of portion of, 494
Ione tungsten mine, Kern County—see Major, 274
Iowa Geological Survey, 306
Iron Canyon bentonite mine, Kern County, 276
Iron Hat gold claims group, Kern County, 225, 261
Iron Mountain iron deposit, Kern County, 270
Iroquois mercury claim, Napa County—see La Joya Mine, 39
Irvine, C. A., and Patterson, W. A.—gold, Kern County, 258
Isabella limestone deposit, Kern County, 279
I. X. L. Quartz Ledge, Butte County, 445

J

Jacalitos oil field, characteristics, 384, 399, 414
Jack Rabbit gold mine, Kern County—see Ferris, 258
Jack & Jim gold mine, Butte County, 446
Jackpot gold mine, Butte County, 446
James, E. J. & Brothers, gold, Butte County, 449
Janney, John, gold, Kern County, 225, 261
Jarosite, Lake County deposit, 527
Jasmine area, Kern County, oil production 1940-47, 283
Jawbone Canyon clay, Kern County, 246, 277
Jenkins, Olaf P., *Annual report, California Division of Mines, 99th fiscal year*, 7-29
Jennette gold mine, Kern County, 261
Jennette-Grant antimony deposit, Kern County, 207, 252; gold mines, 225-226, 252, 261
Jenny Lind gold claim, Kern County—see Sunrise, 233-234, 268

Jensen, Nan C., Bowles, Oliver, and—*Industrial uses of limestone and dolomite*, 319-334
Jewitt, Mrs. Grace, gold, Kern County, 265
Johnson, Carl, gold, Butte County, 440
Johnson, F. T., and Ricker, Spangler, *Ione-Carbondale clays, Amador County, California*, 491-498
Johnston Rock Co., Butte County—see Butte Creek, 435-436, 441
Joints, map symbols used by the U. S. Geological Survey, 113
Jones, A. E., gold, Butte County, 450
Jones, J. Wesley, Pantoscope, S-61-62
Jones, Paul, gold, Butte County, 450
Josephine gold mine, Kern County, 226, 261 (two)
Joslyn, Evelyn P. (and others), gold, Butte County, 445
Juan Dosie gold mine, Kern County, 262
Jumbo gold mines group, Kern County, 226-227, 262
Jumper gold mine, Tuolumne County, 69
Junction gold mine, Tuolumne County, 68-69
Jurassic, Oakville district, Napa County, 35

K

Kaher, Oscar J. and Mabel J.—gold, Butte County, 447
Kaiser, Henry J., Co., gravel plant, Butte County, 437, 446; photo, pl. 20A
Kammererite, Calaveras and Tehama County deposits—see chlorite, 523
Kansas Geological Survey, 306-308
Kaolinite, properties important in water-flooding oil reservoirs, 139
Karma gold mine, Kern County, 227, 262
Katydid gold quartz, Butte County, 446
Kelly Hill gold mine, Butte County, 428, 446
Kelso Creek gold placers, Kern County, 262
Kelso tungsten mine, Kern County—see Tejon Ranch Co., 276
Kemen Gravel Pit, Butte County, 437, 446
Kennedy Gravel Pit, Butte County, 437-438, 446
Kennedy, John, bentonite, Kern County, 245, 276
Kent, E. A., Tuolumne County dredging operations, 73-74
Kentucky Department of Mines and Minerals, 308
Keohn, Charles, gold, Kern County, 260
Kermesite, Kern County deposit, 527
Kern Bluff area oil field: characteristics, 381, 396, 411; production 1940-47, 286-287
Kern County, mineral occurrences—brookite, 523; cassiterite, 523; howlite, 526; inderite, 527; kermesite, 527; ludwigite, 527; phillipsite, 529; probertite, 529; scheelite, 531
    mineral resources, 203-297, pls. 9-18: map showing mines and mineral deposits, pl. 17; minerals, metallic, 206-241, nonmetallic, 241-250; mines, tabulated list, 252-279; production 1946, table showing, 280; 1880-1946, table showing, between 206-207
    oil and gas resources, 280-297: crude production and proved acreage by fields, 294; fields of western, map, pl. 18; petroleum reserves, estimated, 281-282
    , streams, 205
    , topography, 205
    , transportation, 205-206
Kern Development Co., gold, Kern County, 211-212, 253, 254, 255, 256, 266, 268
    Front oil field, Kern County: characteristics, 381, 396, 411; production 1940-47, 286
    Land and Development Co., antimony, Kern County, 207, 252
    Mines, Inc., gold, Kern County, 211, 254
    River Mining Co., gold, Kern County, 262
    River oil field, Kern County: characteristics, 381, 396, 411; production 1940-47, 286
Kettleman North Dome oil field, characteristics, 385, 400, 415
Keyes gold mine, Kern County, 262
Keystone & Golden Fashee gold mine, Butte County, 446
Kickapoo gold property, Butte County, 446
Kiester, A. H., gold, Kern County, 256
King, David, gold mines group, Kern County, 256
    , George, gold, Kern County, 267
    Solomon gold mine, Kern County (two), 262
    Solomon Gold Mining Co., Kern County mine, 227, 262
    tungsten mine, Kern County, 273
Kister, Len, gold property, Butte County, 427-428, 444
Knapps, Rolland E. and Harold F.—gold, Butte County, 445
Knight, Goodwin J., gold, Kern County, 257, 258, 259, 260
Knox, Edgar, gold, Butte County, 451
Kobes, Oscar J. and Mabel, gold, Butte County, 440

Koehn, Chas., clay, Kern County, 277
Kramer, Henry, limestone, Kern County, 278
Kreta, John, gold-tungsten, Kern County, 213, 254, 272
Kutzner, H. J., tungsten, Kern County, 273

L

La Crosse gold mine, Kern County, 262; see also Lucky Boy, 263
La Joya mercury mine, Oakville district, Napa County, 39-43: geologic map, pl. 1; geology, 41-42; history, 39-41; map of underground workings, pl. 2; suggestions for further exploration, 42-43
Lacy, Mrs. ———, gold, Kern County, 255
Ladd, O. H., gold, Kern County, 227-262
Lady Belle gold mine, Kern County—see Big Blue, 211-212, 254
Laird, Wilson M., State Geological Surveys, 299-317
Lake County mineral occurrences: copiapite, 524; curtisite, 525; epsomite, 525; jarosite, 527; marcasite, 528; millerite, 528; stibnite, 532; tiemannite, 533
Lambert, G. W., Jr., gold, Butte County, 441
Lancha Plana Gold Dredging Co., dredge No. 3, Butte County, 428, 447; photo, pl. 20B
Land, Federal Department, now Bureau of Land Management, 468-469
  grants, Spanish and Mexican, 473-478; to states, 478-481
  Management, Federal Bureau of, 468-469
  , public, Atomic Energy Act of 1946 ruling concerning, 342-343
    , classification as to character, 470-472
    , federal system, 465-468
    , surveys, 469-470; resurveys, 470-471
  , school, Act of 1927 granting mineral land to states, and amendments, 487-490
    , indemnity grants in lieu of, 485-487
    , time state's title takes effect, 481-485
Larkin, Thomas C., To the Editor of the New York Sun, 1846, S23
  , To James Buchanan, June 1, 1848, S41-42; June 28, 1848, S43-47
Last Chance: gold lode, Butte County, 447; gold mine, 447
Laurel gold mine, Kern County, 263
Lawndale oil field, characteristics, 373, 387, 403
Lawsonite, Sonoma County deposit, 527
Lazar pocket mine, Tuolumne County, 69
Lead, red, use in rubber industry materials, 559
Lead, Tuolumne County, 75
Lead-silver, Butte County, 433
Lead-zinc properties, Kern County, 238, 270
Leather, limestone in tanning of, 333
Lechatelierite, Riverside County deposit, 527
Lehigh Valley gold mine, Kern County, 263
Levant gold quartz mine, Butte County, 447
Lewis, Harriet, gold, Butte County, 447
Library section, California Division of Mines, 12-15
Lida gold mine, Kern County, 263
Light, P. R., and Walker, C. F., gold, Kern County, 263
Lime and limestone, use in pulp production, 460-461
Lime, hydrated, use in rubber industry materials, 558
Lime included with limestone, industrial use, 325
Limestone and dolomite, industrial uses, 319-334; and marble, Tuolumne County, 76-80
  , Butte County, 433
  consumed in United States for principal chemicals and processing applications, 1921-45, table showing, 320-324
  bedrock exposed by early-day placer mining, Columbia, photo, pl. 7B
  , Black Leg Creek, Tuolumne County, geologic map and structure sections, pl. 24
  composition, 325
  mine, Tuolumne County, geologic map of part of, pl. 25
  near Gazelle, Siskiyou County, 514-520, pl. 26: description of deposits, 519-520; economic evaluation, 520; geologic map and structure sections, pl. 26; geology, 515-519; index map of area, 515; limestone deposits, 519-520; lithology and chemical composition, 519-520; location and accessibility, 514; photo, 516; stratigraphy, 517-518; structure, 518-519; table showing analyses, 520; topography and drainage, 515
  near Sonora, Tuolumne County, geology of, 509-513, pls. 24, 25: description of deposits, 510-511; economic geology, 512-513; geologic structure, 511-512; general geology, 510; lithologic and chemical characteristics, 510-511; location and accessibility, 509; table giving partial analyses, 512; topography and drainage, 510

Limestone (continued)
    , U. S. Bureau of Mines report of 1941, 325
    , U. S. consumption for chemical and processing uses: 1945, table by uses, 326; 1921-45, table by years, 320-324
Lineations, map symbols used by U. S. Geological Survey, 113
Litharge, use in rubber industry materials, 558
Lithopone, use in rubber industry materials, 558
Little Angel gold mine, Kern County, 263
    Bonanza gold mine, Kern County, 263
    Butte Min. & Mill. Co., gold, Kern County, 263
    Charlie gold mines, Kern County—see Croesus group, 256
    , D. R., and Hockett, Fred, gold, Kern County, 225, 260
    Dick and Good Hope tungsten mine, Kern County, 273
    Frog gold quartz, Butte County, 447
    Gem gold mine, Tuolumne County, 69
    Joe gold mine, Kern County, 263
    Pippin gold mine, Butte County, 447
    Wonder tungsten mine, Kern County, 273
Livesly, Roy D. and Jennie, gold, Butte County, 440
Locarno gold-tungsten mine, Kern County, 228, 263
Locarno-Simon gold-tungsten group, Kern County—see Locarno, 228, 263
Lodestar gold mines, Kern County—see Golden Queen, 220-223, 259
Logan, Clarence A., *Mines and mineral resources of Tuolumne County, California*, 47-83, pls. 4-8
Lompoc oil field, characteristics, 378, 393, 408
Lone Star Mining Co., gold, Kern County, 228-229, 263
Long Beach oil field, characteristics, 373, 388, 403
Long Beach Salt Co., Kern County, 250-279; photo, pl. 15
Long Tom Min. & Mil. Co., gold, Kern County, 263
Long Tom, use in gold mining, 1848-57, S87-89
Longfellow gold mine, Tuolumne County, 69-70
Los Angeles City oil field, characteristics, 373, 388, 403
Los Angeles County mineral occurrences: analcime, 522; realgar, 530; zircon, 534
Lost Hills oil field, Kern County: characteristics, 381, 396-397, 411-412, photo, pl. 12A, production 1940-47, 288; water-injection project, 366-367
Lost Keys gold mine, Kern County, 263
Lott, C. F., coal, Butte County, 421, 447
Louisiana Geological Survey, 308
Love Point gold mine, Butte County, 447
Lovett, M. J., and Price, W. M.—tungsten, Kern County, 275
Lucy, A. R. (?), gold, Kern County, 263
Lucky Boy gold mine, Kern County, 229, 263
Lucky John gold mine, Butte County, 447
Ludwigite, Kern County deposit, 527
Lund, Nelson E., clay, Butte County, 447
Lydia gold placer, Butte County, 447
Lynds, Mrs. Louise R., gold, Butte County, 445

M

MacArthur, General, tungsten group, Kern County, 273
Macco Construction Co., clay, Kern County, 245, 277
Mack gold mine, Tuolumne County, 70
Mackey Ranch copper mine, Tuolumne County, 53; scheelite, 82
Madera County, scheelite occurrence, 531
Magalia Cons. gold mine, Butte County—see Mineral Slide, 448
Magalia Mining Co., gold, Butte County, 428-429, 443, 448
Magee, H. H., Kern County oil production, 287, 290
Magnesia, calcined, use in rubber industry materials, 558
Magnesia, dolomite in manufacture of, 332
Magnesite, Tuolumne County, 80-81
Magnesium carbonate, basic, use in rubber industry materials, 558
Magnesium metal, dolomite as an ore of, 333
Magnetite, San Bernardino and Shasta County deposits, 527-528
Mahary and Hougthawoth, antimony group, Kern County, 252
Maine Geological Survey, 308
Major tungsten mine, Kern County, 274
Maki magnesite claims, Tuolumne County, 81
Maltby gold placer, Kern County, 263
Mammoth-Gold Bank Cons. gold mine, Butte County, 448
Mammoth gold mine, Butte County, 426, 441
Mammoth Mountain Mining Co., gold, Kern County, 263
Manganese, Butte County, 434
Manganite, Imperial County deposit, 528
Mann copper mine, Tuolumne County, 53-54

Map symbols used in publications of U. S. Geological Survey, 109-116
Marble Walls and Marble Halls gold placer, Butte County, 448
Marcasite, Lake County deposit, 528
Marin County, szaibelyite occurrence, 533
Mariposa County, chromite occurrence, 524
Marshall, James W., To J. M. Hutchings, on the discovery of gold, January 24, 1848, S27-29
Martens, Henry, gold, Butte County, 447
Martin, Billie, sand and gravel, Butte County, 438, 448
Martino, J., gold, Kern County, 267
Maryland Dept. of Geology, Mines and Water Resources, 308
Mascagnite, Sonoma County deposit, 528
Mason, Col. R. B., To Gen. R. Jones, August 17, 1848, S50-57
Master Key gold claims group, Kern County, 229, 264
Matthews, Roy, sand and gravel, Butte County, 438, 448
Mattye gold mine, Butte County, 432
Mayhall Ranch, limestone and marble, Tuolumne County, 77-78
McAdams, A. B., and Wiggins, J. M., antimony, Kern County, 207, 252
McAuliffe, P. W., gold, Kern County, 267
McCann patented gold claim, Tuolumne County—see Harvard, 68
McCormick chrome mine, Tuolumne County, 52-53
McCormick Estate, limestone, Tuolumne County, 78
McCormick, Judge Paul J., gold, Kern County, 258
McDonald Anticline area oil field, Kern County: characteristics, 382, 397, 412; production 1940-47, 289
McFadden, Laura N., gold, Kern County, 257
McGinnis, E. B., gold, Kern County, 264; and O'Leary, J. T., gold, 267
McHugh, P. J., gold, Butte County, 442 (two), 448; and Andy L., gold, 450
McKeadney gold mines, Kern County—see Ederl Mines, Ltd., 257
McKee, T. J. and N. T., tungsten, Kern County, 275
McKidney gold mine, Kern County, 264
McKinney, Chas., clay, Kern County, 277
McKittrick oil field, characteristics, 382, 397, 412
McKittrick-Cymric oil field, Kern County: fields and pools discovered 1944-47, 290; production 1940-47, 289-291
McLain gold mine, Butte County—see Shawnee, 430, 451
McLain, Lewis H., gold, Butte County, 453
McLean, Anna G., gold, Butte County, 444, 448; soapstone, 434; talc, 448
McLean limestone deposit, Tuolumne County, 78
McPherson Ranch limestone deposit, Tuolumne County, 78
Meek-Hogan tin deposit, Kern County—see Hogan-Mallery, 238-239, 271
Melanterite, Alpine and Sonoma County deposits, 528
Menke-Hess gold placer, Tuolumne County, 74
Merrill, Grant P., tungsten, Kern County, 273
Merrill, Warner, tungsten group, Kern County, 274
Mesa oil field, characteristics, 378, 393, 409
Mesozoic sedimentary rocks, Oakville district, Napa County, 34
Metallurgy: at Penn mine slag dump, 103-104; (flux), limestone use as, 327
Meuer and Gerbracht, Kern County mines: perlite, 249-279; pumice, 249, 250, 279
Mica, use in rubber industry materials, 559
Michigan Geological Survey Division, Dept. Conservation, 309
Middle Butte Mine, Inc., gold, Kern County, 215-216, 229, 255, 264
Midway-Sunset oil fields group, Kern County: characteristics, 382, 397, 412-413; production 1940-47, 291
Milham Exploration Co., oil field, Kern County, 297
Miller, Andrew, gold placers, Kern County, 262
  , Mrs. Gus, gold mine, Kern County, 268
  , Mrs. Hallah, gold, Kern County, 233-234, 268
Millerite, Lake and Napa County deposits, 528
Milwaukee Mining Co., gold, Kern County, 230, 264
Mine water, Penn mine slag dump, Calaveras County, 104-105
Mineral deposits and mine workings, map symbols used by U. S. Geological Survey, 114
  Economics Section, California Division of Mines, 17-19
  food, agricultural use of calcium for, 332
  grain surface forces in oil sands, influence on water-flooding, 135-137
  lands in school sections, indemnity grants in lieu of, 485-487; laws and amendments, 485-490; states' titles to, 481-485
  materials, inorganic, used in rubber industry materials, list, 555
  paint, Butte County, 434, 449
  resources, mines and—Butte County, 417-454, pls. 19-23; Kern County, 203-297, pls. 9-18; Tuolumne County, 47-83, pls. 4-8
  Slide gold mine, Butte County, 448
  Springs, Butte County, 434

Minerals commodity survey, California Division of Mines, 19-21
  in Oakville quicksilver deposits, 37
  in sedimentary rocks, table showing frequency of occurrence, 136
  of California, Bulletin 136: errata, 521; references, 535-540; supplement No. 1 to, 521-540
  , oil reservoir sandstones content: influence on water-flooding, 133-135; summary and correlation to California conditions, 143-144
Mineralogical and geological characteristics, California oil fields, 369-370, 386-400
  characteristics of oil sands, influence on water-flooding, 132-133
Mineralogy Section, California Division of Mines, 15-17
Mining law in recent years, 465-490
Minnehaha gold-tungsten mine, Kern County, 264
Minnesota Geological Survey, 309
Mintern, C. C., tungsten, Kern County, 274
Mintern states, tungsten, Kern County, 276
Miranda, Theodore, tungsten, Kern County, 274
Mispley, R. G., *The western pulp and paper industry as a consumer of chemicals*, 459-464
Mississippi Geological Survey, 309
Missouri Division of Geological Survey and Water Resosurces, 309-310
Mizpah-Montana Mining Co., silver, Kern County, 271
Mizpah-Nevada Mining Co., silver, Kern County, 271
Mohawk-Buddy gold mine, Kern County, 264
Mohrman gold mine, Tuolumne County, 70
Mojave Corp., clay, Kern County, 277; silt, 246, 277
  Desert Agricultural Gypsum, Kern County, 248-249, 278
  Min. & Mil. Co., gold, Kern County, 257
Molybdenite, Riverside County deposit, 528
Molybdenum, Tuolumne County, 81
Monarch gold mine, Kern County, 230, 264
Monarch Rand Mining Co., silver-gold-tungsten, Kern County, 271
Monazite, Riverside County deposit, 528
Mono County mineral occurrences: scheelite, 531; zoisite, 534
Monolith Portland Cement Co, Kern County, 244-245; gypsum, 248, 278; limestone, 279; plant photo, pl. 11A; quarry photo, pl. 11B
Monrovia gold claim, Kern County—see Valley View, 236, 269
Montalvo, West, oil field, characteristics, 376, 391, 406
Montana Bureau of Mines and Geology, 310
Monte Christo gold mine, Butte County, 448
Montebello oil field, characteristics, 373, 388, 403
Monterey County mineral occurrences: aragonite, 522; cinnabar, 524
Montmorillonite, properties important to water-flooding oil reservoirs, 139
Moody Gulch oil field, characteristics, 379, 393, 409
Moore, Avery, gold placer claims, Tuolumne County, 74
Moore, Tom, antimony mine, Kern County, 252
Moore, Verne, Estate and Associates—gold, Kern County, 267
Moreland, J. E., and Potter, Mrs. J. H., Estate—gold, Kern County, 220, 259
Morgan graphite mine, Tuolumne County, 75
Morris Ravine Mining Co., gold, Butte County, 429, 449
Mother Lode, The, Tuolumne County, 55
Mount Breckenridge iron mine, Kern County, 270
Mount Poso oil fields group: characteristics, 382, 397, 413; production 1940-47, 283
Mountain House drift gold prospect, Butte County, 449
Mountain View oil field, Kern County: characteristics, 383, 398, 413; production 1940-47, 287-288
Mountain View tungsten mine, Kern County, 274
Mowry & Newman, gold, Butte County, 450
Mudd, Harvey S., gold, Kern County, 266
Mullin & Co., Tuolumne County dredging operations, 74
Murdoch, Joseph, *Minerals of California, Supplement No. 1 to Bulletin 136*, 521-540
Muroc clay deposit, Kern County, 277
Muroc silt deposit, Kern County, 246, 277
Murphy Bros. Ranch, limestone, Tuolumne County, 78
Musante Ranch, limestone, Tuolumne County, 78-79

N

Naja tungsten mine, Kern County, 274
Napa County: millerite occurrence, 528; Oakville district quicksilver deposits, 31-46; napalite occurrence, 528
Napalite, Napa County deposit, 528
Napoleon gold mine, Kern County—see Santa Ana, 267
Natural gas, Butte County, 434
Natural resources, stimulated development, 300
Nebraska Conservation and Survey Division, 310-311

Nestell and Burns, gold, Kern County, 260
Nevada Bureau of Mines, 311
New Alvarado gold placer, Butte County, 449
    Dawn gold placer, Kern County—see Chamberlain group, 217, 256
    Era gold placer, Butte County, 449
    Hampshire Mineral Resources Committee, 311
    Jersey Bureau of Geology and Topography, 311
    Mexico Bureau of Mines and Mineral Resources, 311-312
    World gold claim, Kern County—see Sunrise, 233-234, 268
    York State Science Service, Office of the State Geologist, 312
Newhall oil fields group, characteristics, 373, 388, 403
Newhall-Potrero oil field, characteristics, 374, 389, 404
Newport, West, oil field, characteristics, 374, 389, 404
Nimshew Gold Mining Co., gold, Butte County, 443
Nisket Lode and Standard gold mine, Butte County, 449
Nonmetallic minerals, Kern County, 241-251, 276-279
Norden gold placer mine, Kern County, 264
Norman, Charles, and Holohan, G. J., gold, Kern County, 264
North Carolina Mineral Resources Division, 312
North Dakota Geological Survey, 312-313
North Star gold mine: Butte County, 449; Tuolumne County, 72
North Sumner Gold Mines, Inc., Kern County, 264
Norton gold quartz, Butte County, 449
Nuevite, Riverside County deposit, 529
Nugget drift gold mine, Butte County, 449

O

Oak Canyon oil field, characteristics, 374, 389, 404
Oak Hill copper mine, Tuolumne County, 54
Oakeshott, G. B.; Tucker, W. B., Sampson, R. J. and—*Mineral resources of Kern County*, 203-297
Oakville mercury claim, Napa County—see Bella Oak, 43-44
Oakville quicksilver district, Napa County, 31-46, pls. 1-3: deposits, 37-38; geography, 33; geology, 34-37; history, 33; index map showing location, 32; map showing, 36; mines and prospects, 39-46; prospecting suggestions, 38-39; table showing production 1872-1943, 34
O'Brien, J. C., *Mines and mineral resources of Butte County, California*, 417-454, pls. 19-23
Oceanic Oil Co, Kern County, 286-287
Occident mercury claim, Napa County—see La Joya, 39
Ochre claims, Nos. 1 and 2, Butte County, 434, 449
Ochre, use in rubber industry materials, 559
O'Connor, D. J., and Rubbert, M. L., gold, Kern County, 263
O'Hara gold mine, Tuolumne County, 70
Ohio Geological Survey, 313
Oil accumulation: in California, table showing types, 130; in Kern County fields, major structural control, 284
Oil and gas fields, Kern County, location, 280
Oil and gas, Kern County, 280-297; development and production 1940-47, 283-297; geologic occurrence, 283; reserves, 281
Oil, crude, influence of polar impurities content on water-flooding in California, 549; production and proven acreage by fields, Kern County, 294
Oil fields, California, characteristics, 367-416: geological and mineralogical, table showing, 369-370, 386-400; physical, table showing, 368-369, 371-385; water and oil, and production, table showing, 370, 401-415
    , Kern County, recent general developments, 283
Oil phase in relation to water-flooding, 152-155
Oil production in California by water-flooding: conclusions and recommendations, 550; current and proposed research, 541-551; factors influencing application of, 129-202; survey of conditions relative to application of, 363-416
Oil reservoirs, California, water-flooding, 123-202, 363-416, 541-551: capillary and surface effects, 171-174; characteristics of fields, 367-416; clay content influence on, 548, 549; conclusions and recommendations concerning, 550-551; distribution and nature of fluids, 151-162; economics, 195-199; fluid displacement principles, 174-177; fluid flow principles, 177-182; fluid saturation, 162-171; "formation factor," significance in electrical logging, 549; geological conditions influencing, 129-132; gravity segregation effects in, 547-548; history of, 364-367; injection rates and pressures, 182-187, 550; legal problems affecting, 547; liquid-solid interfacial tension measurements with relation to, 549;

Oil reservoirs, California (continued)
    mineralogical characteristics influencing, 132-144; physical problems, 547-550; physical properties of the porous medium, 144-151; problems in application of, 547-550; research, current, 544-547; current and proposed, 541-551; past, 542-544; sand pores, investigation of, 548; selective plugging methods, 550; well spacing completion and behavior, 187-195
Oil, total and recoverable, calculations of, 167-168
    , water and—characteristics and production from California oil fields, 370, 401-415
    well drilling, delayed, influence on water-flooding, 192
        patterns for water-flooding, 188-189
        spacing for water-flooding, completion and behavior, 187-195
    wells, injection—behavior in water-flooding, 193-195
        , old—use of for water-flooding, 191
Ojai oil fields group, characteristics, 376, 391, 406
Oklahoma Geological Survey, 313
Old Bader gold mine, Butte County—see Pitts, 450
Old Cowboy gold mine, Kern County, 230-231, 265
Olivine, Shasta County deposit, 529
Opal pumice deposit, Kern County, 250, 279; photo, pl. 9
Opal, Sonoma County deposit, 529
Operator Cons. Mines, gold, Kern County, 265
Ophir gold mine, Kern County, 265; see also Ederl Mines, Ltd., 257
Ophir-Zuck tungsten mine, Kern County—see Tungsten Chief, 275
Opportunity gold mine, Kern County, 265
Orange Blossom copper mine, Kern County, 208-209, 253
Ordonez de Montalvo, Garci, On the golden "island" California, 1510, 89
Ordovican dolomite, barium occurrence in, 88
Ore bodies, size and grade, Oakville district, 38
Ore buyers' inspection, California Division of Mines, 28
Ore deposits, structural control of, Oakville district, 37-38
Oregon Department of Geology and Mineral Industries, 313-314
Oro Fino gold mine: Butte County, 449; Kern County, 265
Oroville Gold Dredging Co., gold, Butte County, 429-430, 449
Oroville gold mine, Butte County, 450
Orphan Girl gold mine, Kern County, 265
Orrell, Lee, tungsten group, Kern County, 240-241, 272
Osdick, P. J. (?), gold, Kern County, 266
O'Sullivan, J. B., and Bacon, E. L., gold, Butte County, 444
Oxides of iron, brown, use in rubber industry materials, 556; red, 559
Owl tungsten mine, Kern County, 274; see also King, 273
Oxnard oil field, characteristics, 376, 391, 406

P

Pacific Coast Borax Co., Kern County (two mines), 241, 243, 276; photo, pl. 16
    Exploration Co., Kern County, 290
    Gypsum Co., Kern County, 249, 278
    Investment Co., gold, Butte County, 443
    mercury claim, Napa County—see La Joya Mine, 39
    Mines Corp., lead-silver, Kern County, 271
    Oil and Gas Development Corp., Kern County, 283
    Patented gold claim, Tuolumne County—see Harvard, 68
    Western Oil Co., Kern County, 290
Pagett, Frank E. and Maria A., gold, Tuolumne County, 70
Paleozoic sediments, barium occurrence in, 89
Paloma oil field, Kern County: characteristics, 383, 398, 413; production 1940-47, 295
Panmarat gold quartz lode, Butte County, 450
Paper, limestone in manufacture of, 328-329
Paper manufacture, fillers and coating materials, 463
Paper, pulp and—consumer of chemicals in western industry, 459-464
Paris silver-gold group, Kern County—see Gold Cross and Standard, 219, 258
Parks chromite mine, Butte County, 450
Parrott and Allec silica deposit, Kern County, 279
Pascoe, C. W., tungsten, Kern County, 273, 275
Patch, H. K., gold, Kern County, 263
Patten, Peyton, Higgins, Ellis, McCornell—tungsten, Kern County, 273
Peach, Garden, gold, Butte County, 452
Pearl Wedge gold mine, Kern County, 265
Pedro, A., et al., Estate, graphite, Tuolumne County, 75
Peep, J., gold, Kern County, 261
Penn copper mine, Calaveras County: assay map, 101; history, 102; metallurgy, 103-104; mine water, 104-105; physical features, 102; surface plan, 100; table of analyses and computed metal content, 103; U. S. Bureau of Mines work at, 102-103; volatilization test on, 103

Penninite, Calaveras and Tehama County deposits,
Pennsylvania gold mine, Kern County, 265
Pennsylvania Bureau of Topographic and Geologic Survey, 314
Pennsylvania gold mine, Kern County, 265
Perkins, Clem G., and Martin, Ruby I.—gold, Butte County, 440
Perlite deposits, Kern County, 249, 279
Permeability of oil reservoirs, importance in water-flooding, 147-151
Perschbaker gold mine, Butte County—see Magalia, 428-429
Petalite, San Diego County deposit, 529
Peterson, T. B., gold, Kern County, 229, 263
Petroleum refining, lime used in, 334
Petroleum reserves, estimated, Kern County, 281-282
Phillips, O. A., and Spearman, D. S.—gold, Kern County, 265
Phillipsite, Kern County deposit, 529
Phlogopite, Riverside County deposit, 529
Phoenix gold mine, Butte County, 450; Kern County—see Operator Cons, 265
Lake Granite Co., stone quarry, Tuolumne County, 82
Phosphosiderite, San Diego County deposit, 529
Pico, Juan Jose, On rumors of gold before 1840, S13
Pierrel, C. E., gold, Kern County, 268
Pine Grove gold mine, Butte County, 450
Pine Tree gold-tungsten mine, Kern County, 265
Pinmore gold mine, Kern County, 265
Piru area oil field, characteristics, 377, 391, 407
Pitticite, Tuolumne County deposit, 529
Pitts gold mine, Butte County, 450
Piute Cons. Mining Co., gold, Kern County, 265
Piute gold mine, Kern County, 265
Piute Mines, Ltd., gold, Kern County, 224, 260
Piute Mining Co., gold, Kern County, 215, 255
Placer County, idocrase deposit, 527
Plasse, A. H., tungsten, Kern County, 274
Platinum-group metals, Butte County, 434
Play Boy tungsten mine, Kern County, 274
Playa Del Rey oil field, characteristics, 374, 389, 404
Pleasant Valley oil field, characteristics, 385, 400, 415
Pleasant View gold mine, Kern County—see King Solomon, 262
Pleistocene, Oakville mercury district, 35
Pliocene, Oakville mercury district, 35
Pocket mines, Tuolumne County, 56
Polar Bear gold mine, Kern County, 265
Pore patterns in oil sands: displacement from individual, 176-177; texture and—relation to water-flooding, 144-147
Porosity in porous medium of oil sands, relation to water-flooding, 147
Porous medium of oil sands: physical properties with relation to water-flooding, 144; summary and relation to California conditions for water-flooding, 151
Porphyry Point gold mine, Butte County—see Silver Moon, 452
Port Stockton Cement Co., limestone, Tuolumne County, 79
Porter gold mine, Butte County, 450
Poso Creek oil fields, Kern County: characteristics, 383, 398, 413; production 1940-47, 286
Poso Min. and Mil. Co., gold, Kern County, 266
Post, Jack L., gold, Butte County, 448
Potrero oil field, characteristics, 374, 389, 404
Poultry grit, limestone used for, 334
Powell, A. M., tungsten, Kern County, 275
Pre-Built Homes Co., gypsum production—see Gypsum, Inc., 248
President gold mine, Kern County, 266
Price, supply and demand, of water-flooding oil reservoirs, 198
Primal gold lode, Butte County, 450
Princess gold mine, Butte County, 451
Probertite, Kern County deposit, 529
Processing industries, limestone in miscellaneous, 334
Production and water and oil characteristics, California oil fields, 370, 401-415
Prospects, mercury, Bella Oak and La Joya mines, 46
Prosperity tungsten mine, Kern County, 274
Psilomelane, Imperial County deposit, 530
Pulp and paper industry, western, 459-464: approximate annual consumption of chemicals by, table showing, 461; chemicals used for pulp production, primary, 462-463, secondary, 462: fillers and coating materials used in, 463: opportunities for development of resources in connection with, 263-264; pulping process employed in, 460; sizing materials used in, 462-463
Pumice deposits, Kern County, 249-250, 279

Pumpellyite, San Mateo County deposit, 530
Punch Bowl gold placer, Tuolumne County, 74-75
Putman, H., gold, Kern County, 262
Pyarin, tungsten group, Kern County, 274
Pyle, Edward, gold, Kern County, 232
Pyramid gold mine, Kern County, 266
Pyramid Hills oil field, characteristics, 385, 400, 415
Pyrolusite, Imperial County deposit, 530
Pyromorphite, Inyo County deposit, 530
Pyrophyllite, Inyo and San Diego County deposits, 530
Pyroxenes, Contra Costa and Riverside County deposits, 530

Q

Quartz mining in California, 1848-57, S101-115
Quartz, San Bernardino County deposit, 530
Quartzose in oil reservoir sandstones, 133
Queen Esther gold mine, Kern County, 266
Quicksilver, Oakville district, Napa County deposits, 31-46, pls. 1-3: geology, 34-37; mines and prospects, 39-46; table showing production, 34
Quirk, John, asbestos, Butte County, 421

R

Radcliffe tungsten mine, Kern County, 275
Rainbow gold mine, Butte County, 451
Raisin City oil field, characteristics, 385, 400, 415
Ramey, Geo., and Hicks, H. D.—tungsten, Kern County, 274
Ramey, J. E., et al., tungsten, Kern County, 273
Rand Contact Mining Co., silver, Kern County, 271
    Gold Dredging Asso., gold-tungsten, Kern County, 231, 266
    gold mine, Kern County, 266
    gold placers, Kern County, 266
    tungsten mine, Kern County—see Major, 274
Randolph, Mrs. E. C., gold, Kern County, 253
Rattlesnake gold quartz mine, Butte County, 451
Rattlesnake lead-silver-gold group, Kern County, 266, 271
Rawhide asbestos claims 1, 2, 3, Tuolumne County, 49
Rayburn, Mrs. ———, gold, Kern County, 257
Realgar, Los Angeles County deposit, 530
Red Gravel gold mine, Butte County, 451
Red Hill gold mine: Butte County, 451; Kern County, 266
Red Wing gold mine, Kern County, 231-232, 266
Reese, Kate, Estate, gold, Kern County, 268
References, Minerals of California, 535-540
Reform gold mine, Kern County, 266
Refractories, dolomite and limestone as substitutes for, 328
Relief patented lode claims, Criss Cross and—Tuolumne County, 62
Reports published by California Division of Mines, 99th fiscal year, 25-27
Reserves: oil and gas, Kern County, 281-282; quicksilver ore, Oakville district, 39
Restored-state method of fluid saturation in petroleum reservoirs, 165-166
Reynolds, F., gold, Kern County, 259
Rhode Island Industrial Commission, Mineral Resources Committee, 314
Rhodonite, Tulare County deposit, 530
Ricardo gold placers, Kern County, 267
Richardson Springs Corp., mineral springs, Butte County, 434, 451
Riches and Wealth gold placer, Kern County, 267
Richfield Oil Corp., Kern County, 293, 295
Richfield oil field: characteristics, 374, 389, 404; experimental water-flooding project, 364-365
Ricker, Spangler; Wiebelt, Frank J. and—*Ione-Carbondale clays, Amador County, California*, 491-498; *Penn mine slag dump and mine water, Calaveras County*, 99-105
Riebeckite: Sonoma County deposit, Tulare County deposit—see amphibole, 522
Riley clay deposit, Kern County, 246, 277
Riley, L. F., clay, Butte County, 452
Rincon Area oil field, characteristics, 377, 391, 407
Rio Bravo oil fields, Kern County: characteristics, 383, 398, 413; production 1940-47, 292
River mining for gold, 1848-57, S97-101
Riverdale oil field, characteristics, 385, 400, 415
Riveredge gold placers, Kern County, 232, 267

Riverside County mineral occurrences: anatase, 522; boehmite, 523; brucite, 523; chondrodite, 524; cristobalite, 525; cyrtolite, 525; diopside, 525; dumortierite, 525; geikielite, 526; lechatelierite, 527; molybdenite, 528; monazite, 528; nuevite, 529; phlogopite, 529; scheelite, 531; wollastonite, 534; xanthophyllite, 534
Road metal producer, Butte County, 451
Robbers Roost Mining Co., gold, Butte County, 443, 449
Rogers, J. R., tungsten, Kern County, 272
Romerite, Alpine County deposit, 531
Roofing granules: growth of industry, 456-458; in Southwest, 455-458; specifications for raw materials, 458
Roofing, types of, 455-456
Rook, J. C., tungsten, Kern County, 273
Roosevelt gold placer, Butte County, 451
Rosamond clay deposit, Kern County, 277
Rosamond feldspar-silica deposit, Kern County, 246-247, 278
Rose gold mine, Kern County, 267
Rosecrans oil field, characteristics, 374-375, 389-390, 405
Rosin, sizing material in paper manufacture, 462
Ross, H. W., C. B., and George, gold, Kern County, 265
Rothschild-Bender Oil Co., Kern County, 290
Rotten Boulder gold drift mine, Butte County, 451
Round Mountain oil fields, Kern County: characteristics, 383, 398, 413; production 1940-47, 286
Royal Bohee tungsten mine, Kern County, 275
Royal Boyn tungsten mine, Kern County—see Royal Bohee, 275
Royal gold drift, Butte County, 451
Royer, Frank W., gold-silver, Kern County, 268, 271
Rubber industry, description of inorganic mineral materials used in, 564-561
, material of inorganic mineral origin used in, 553-561
, materials specifications, 553-554
Ruby gold mine, Kern County, 267
Rudnick, Oscar, and Brown, P. Sumner—gypsum, Kern County, 247, 278
Run Around copper claims, Kern County—see Copperola, 208
Russell, W. E., gold, Kern County, 264
Rustler and San Diego gold mine, Kern County, 267
Rutile, San Bernardino County deposit, 531
Ryan gold claims group, Tuolumne County, 71

S

Saddle Amended gold placer, Kern County—see Chamberlain group, 217, 256
Saddle gold placer, Kern County—see Chamberlain group, 217, 256
Sailor Boy gold mine, Kern County, 267
St. Charles gold mine, Kern County, 268
St. John gold mine, Kern County, 233, 268
St. Lawrence (Rand) silver-gold mine, Kern County, 268, 271
Sake and Sanders rock pit, Butte County, 438, 451
Salisbury, O. J., clay, Kern County, 277
Salt cake, use in pulp production, 461-462
Salt, Kern County, 250
Salt Lake oil field, characteristics, 375, 390, 405
Sampson gold lode, Butte County, 451
Sampson, R. J., and Oakeshott, G. B.; Tucker, W. B.,—*Mineral resources of Kern County*, 203-297
San Antonio gold mine, Kern County, 267
  Benito County, benitoite occurrence, 523
  Bernardino County mineral occurrences: celestite, 523; embolite, 525; garnet, 525; halite, 526; hematite, 526; magnetite, 527; quartz, 530; rutile, 531; tincalconcite, 533
  Diego County mineral occurrences: helvite, 526; heulandite, 526; petalite, 529; phosphosiderite, 529; pyrophyllite, 530; scheelite, 531; sillimanite, 532; spodumene, 532; stilbite, 532; violarite, 533; wollastonite, 534
  Emidio iron mine, Kern County, 270
  Emigdio antimony mine, Kern County—see Antimony Peak, 252; asbestos mine, 276
  Luis Obispo County, barite occurrence, 522
  Mateo County, pumpellyite occurrence, 530
  Pedro gold claim, Kern County—see Valley View, 236, 269
Sand and gravel, Butte County, 435-439, 441, 446, 448, 452, 453
Sand bodies in oil reservoirs, fluid displacement from, 175-176
Sandstones in oil reservoirs, mineral content, 133-134

Santa Ana gold mine, Kern County, 267
Ana Gold Mines Co., gold, Kern County, 267
Clara County, cinnabar occurrence, 524; stilpnomelane, 533
Fe Springs oil field, characteristics, 375, 390, 405
Maria oil field, characteristics, 379, 393, 409
Maria Valley oil field, characteristics, 379, 394, 409
Paula oil fields group, characteristics, 377, 392, 407
Sargent, A. M., gold, Kern County, 218, 257
Sargent oil field, characteristics, 379, 394, 409
Scapolite, Inyo County deposit, 531
Schaafs, George, gold, Butte County, 443
Scheelite, California deposits, 531-532; Tuolumne County deposits, 82
Schmidt, William, copper, Kern County, 208, 253; gold, 225, 261
School sections, laws governing mineral lands in, 481-490
Scorodite, Tuolumne County deposit, 532
Seaboard Oil Co., Kern County, 289
Seal Beach oil field, characteristics, 375, 390, 405
Sections, map symbols used by the U. S. Geological Survey on, 116
Sedimentary rocks: in oil reservoirs, 133-135; Oakville district, 35; table showing frequency of minerals occurring in, 136
Selenium, use in rubber industry materials, 559
Semitropic gas field, Kern County, production 1940-47, 296
Serpentine, Oakville district, 35
Sespe Canyon oil fields group, characteristics, 377, 392, 407
Sewage and trade-waste treatment, limestone used for, 333-334
Shaft sinking, for gold mining, 1848-57, S91-93
Shafter, C. E., gold, Tuolumne County, 74
Sharpe, J. H., gold, Butte County, 444
Shasta County mineral occurrences: ilvaite, 527; magnetite, 527; olivine, 529
Shaw and Schollar, gold claims, Tuolumne County—see Gross and Street, 66-67
Shawnee gold mine, Butte County, 430, 451
Shell Oil Co., Kern County, 288, 293, 295
Shipsey Mining Co., gold, Kern County, 227, 262, 265
Shuck, F. D., pumicite, Kern County, 251, 279
Sidney gold mine, Kern County, 267
Sierra Talc and Clay Co., clay, Kern County, 277
Sierra tungsten mine, Kern County, 275; see also King, 273
Silica-carbonate rock, Oakville district, 35, 37
Silica, use in rubber industry materials, 559
Sillimanite, San Diego County deposit, 532
Silver-gold deposits, Kern County, 209-238, 252-271
Silver-lead, Butte County, 433
Silver Moon gold mine, Butte County, 452
Silver Queen gold mine, Kern County—see Golden Queen, 220-223, 259
Silverado copper group, Kern County, 209, 253
Simi oil field, characteristics, 377, 392, 407
Simmons, S. L., and McDonald, S. F.—gold, Kern County, 269
Siskiyou County, geology of limestone near, 514-520
, mineral occurrences: bornite, 523; chromite, 524; cinnabar, 524; covellite, 524
Sky Line gold deposit, Kern County, 232, 267
Slate, Tuolumne County, 81
Sledge gold placer, Tuolumne County, 74
Sluicing, ground, use in gold mining, 1848-57, S89-91
Sluicing, use in gold mining, 1848-57, S89-91
Smith, Azariah, discovery of gold January 30, 1848, as recorded in diary of, S33
, Barton, gold, Butte County, 449
, S. C. (?), gold, Kern County, 261, 263
, T. M., and Lambert, E. E.—tungsten, Kern County, 275
, Tom, gold, Kern County, 226, 261
Snell gold mine, Tuolumne County, 71
Snow, Forest, gold, Butte County, 451
Snow White clay deposit, Kern County, 277
Soapstone and talc, Tuolumne County, 81-82
Soapstone, Butte County, 434
Sobrante patented gold claim, Tuolumne County—see Harvard, 68
Soda amphiboles, Sonoma and Tulare County deposits,
Soda ash, use in pulp production, 462
Soda, caustic, used for secondary pulp production, 462
Sodium hydrosulphite, used for pulping process, 462
Sodium silicate, sizing material in paper manufacture, 462
Soledad Extension gold mine, Kern County, 220-223, 259
Somerton, Wilbur H., *Water-flooding as a method of increasing California oil production*, Pt. 1, 123-202; Pt. 2, 363-416; Pt. 3, 541-551

Sonoma County mineral occurrences: alunite, 522; boussingaultite, 523; cinnabar, 524; clinozoisite, 524; epsomite, 525; glaucophane, 526; halotrichite, 526; lawsonite, 527; mascagnite, 528; melanterite, 528; opal, 529; stilbite, 532; tschermigite, 533; voltaite, 534
Sonoma volcanics, Oakville districts, 35
Sonora Marble Aggregates Co., Tuolumne County, 78, 79, plant photo, pl. 6A
Soulsby Belle gold mine, Tuolumne County, 71-72
South Carolina Geological Survey, 314
South Dakota Geological Survey, 315
South Mountain oil field, characteristics, 377, 392, 407
Southern California Marble Co., Kern County, 278
Southern Cross gold mine: Butte County, 452 Kern County—see Uncle Sam, 235-236, 267
Southern oil fields, Kern County, production 1940-47, 295-296
Southern Pacific Railroad Co., clay, Kern County, 246, 277
Spangler, Norman, gold, Butte County, 451
Spanish and Mexican land grants, laws for, 473-478
Sparks gold mine, Butte County, 441
Spessartite, California deposits—see garnet, 525
Sphene, Inyo and Imperial County deposits, 532
Spinel, Inyo County deposit, 532
Split Rock Mines, gold, Butte County—see Morris Ravine, 429
Spodumene, San Diego County deposit, 532
Springer Cons. Mining Co., gold, Butte County, 430, 452
Standard Oil Co. of California, Kern County, 288, 290, 291, 292, 295; Lost Hills water-injection project, 366-367
Standard silver-gold groups, Kern County—see Gold Cross and—219, 258
Standiford, B. D., arsenic, Kern County, 252
Stanford gold mine, Kern County, 267
Stanislaus County mineral occurrences: cinnabar, 524; garnet, 525
Star Dust and Black Cat tungsten mine, Kern County, 275
Star mercury claim, Napa County—see La Joya Mine, 39
Starch, sizing material in paper manufacture, 463
Starlight gold mines, Kern County—see Golden Queen, 220-223, 259
State Geological Surveys, 299, 317; classification of public lands by the, 473
Statistical history of principal industrial limestone uses, 325
Stearns, Abel, On the discovery of gold in California, 1842, S21-22
Stearns Sand & Gravel Co., Butte County, 438-439, 452
Steiffer gold placer, Butte County, 452
Stellar gold claims group, Kern County, 232, 267
Stellerite deposits—see stilbite, 532
Ster (Stoer?), F. J., patented land, Butte County, 442
Stetson, A. W. & Associates, gold, Kern County, 258
Stevens, William, clay, Kern County, 277
Stevenson, A. (and others), chromite, Butte County, 450
Stibnite, Lake County deposit, 532
Stilbite, San Diego and Sonoma County deposits, 532-533
Stilpnomelane, Santa Clara County deposit, 533
Stockton pocket gold mine, Tuolumne County, 72
Stoer (Ster?), F. J., gold, Butte County, 442 (two), 443, 445, 448, 450, 451, 452, 453
Stone industry: Butte County, 435-439, 441, 446, 448, 452, 453; Tuolumne County, 82
Stowe Home Pine Grove gold quartz, Butte County, 452
Strand oil field, Kern County: characteristics, 383, 398, 413; production 1940-47, 293
Stratigraphy in oil wells, influence on water-flooding, 129-131
Streams, Kern County, 205
Street patented gold claims, Tuolumne County—see Gross and Street, 66-67
Strouse, Ed. E. and Chas. J.—gold, Butte County, 445, 447
Structural control, major, in Kern County oil fields, 284
Structure of oil reservoirs, application of water-flooding to types, 129
Struss, Karl, gold, Kern County, 233, 268
Stubblefield, Jessie L., and Ramey, R.—antimony, Kern County, 207, 252; E. A., and Lambert, Earl—gold, 257
Studhorse Canyon antimony mine, Kern County, 207, 252
Sugar, limestone in manufacture of, 331
Sugarman and Nigger gold mine, Tuolumne County, 72
Sulfur, use in rubber industry materials, 559-560
Sukow borax mine, Kern County—see Pacific Coast Borax, 276
Sulphate (Kraft) and soda pulping process, 460
Sulphite pulping process, 460
Sulphur, use in pulp production, 460
Summerland oil field, characteristics, 379, 394, 409

Summit diggings, Kern County—see Summit gold placers, 268
  gold placers, Kern County, 268
  lead-silver group, Kern County, 271
  Lime Co.: limestone, Kern County, 279; tungsten, 275
  mercury mine, Napa County—see La Joya, 39-43
Sumner and North Extension gold mine, Kern County, 268
Sumner gold mine, Kern County—see Big Blue, 254
Sunrise, Jenny Lind, and New World, gold claims group, Kern County, 233-234, 268
Sunset gold mine, Kern County, 268
Sunset Mohawk gold mine, Butte County, 452
Sunset tungsten group, Kern County, 275
Sunshine gold mine, Kern County, 268
Superior Oil Co., Kern County, 290
Surcease Mining Co., gold, Butte County, 430-432, 452, 453; mill photo, pl. 21A; plant yard photo, pl. 21B
Surface openings, map symbols used by the U. S. Geological Survey, 114
Surprise gold mines group, Kern County, 234, 268
Sutter, John A., To J. M. Hutchings, on the discovery of gold, January 24, 1848, S34-38
Sweet tungsten mine, Kern County—see Major, 274
Sweetzer, Nelson W., feldspar-silica, Kern County, 246-247, 278
Swinney, C. Melvin, Fix, Philip F. and—*Quicksilver deposits, Oakville district, Napa County*, 31-46
Syrus Canyon tungsten group, Kern County, 275
Szaibelyite, Marin County deposit, 533

T

Table Mountain Clay Products Co., Butte County, 452
Talc and soapstone, Tuolumne County, 81-82
Talc, use in rubber industry materials, 560
Talleur, Clarence G., gold, Kern County, 219-220, 230-231, 258, 259, 265
Tellurium, use in rubber industry materials, 560
Tehama County mineral occurrences: chromite, 524; copper, 524; garnet, 525; penninite, 523
Tejon Hills area, Kern County, oil production 1940-47, 296
Tejon Hills Oil Co., Kern County, 296
Tejon oil field, Kern County: characteristics, 383, 398, 413; production 1940-47, 295-296
Tejon Ranch Co., zinc-tin, Kern County, 238-239, 271, 276
Templor oil field, Kern County, production 1940-47, 289
Tenderfoot gold quartz, Butte County, 453
Ten Section oil field, Kern County: characteristics, 383, 399, 414; production 1940-47, 293, 295
Tennessee Division of Geology, 315
Terra Lava gold drift mine, Butte County, 453
Texas Bureau of Economic Geology of the University of Texas, 315
Texas Oil Co., Kern County, 290, 295, 297
Thacker, George, gold, Kern County, 267
Tide Water Associated Oil Co., Kern County, 286, 288, 293
Tiemannite, Lake County deposit, 533
Tiger gold mine, Butte County, 453
Tillevite, formula for Ireland specimen, 533
Tin deposits, Kern County, 238-239, 271
Tincalconite, San Bernardino County deposit, 533
Titanium dioxide: pigment in paper manufacture, 463; use in rubber industry materials, 560
Titus, H. E., clay, Kern County, 277
Toadtown gold mine, Butte County—see El Monte, 442
Top of World antimony mine, Kern County, 252, 275
Torrance oil field, characteristics, 375, 390, 405
Tortoise gold placer, Butte County, 453
Townsend feldspar deposit, Kern County—see Rosamond, 278
Transierra Gold Mining Co., Tuolumne County, 72-73
Treasure Hill Mining Co., silver-gold, Kern County, 271
Trestle gold mine, Kern County, 268
Trico gas field, Kern County, production 1940-47, 296
Tridymite, Riverside County deposit, 533
Trinity County, scheelite occurrence, 531
Trio gold claim, Tuolumne County—see Harvard, 68
Triumph Extension gold mine, Butte County, 453
Triumph gold mines Nos. 1 and 2, Butte County, 453
Trojan tungsten mine, Kern County—see El Diablo, 272
Tropico gold mines, Kern County, 234-235, 269; see also Lida, 263, and Piute, 265
Tschermigite, Sonoma County deposit, 533
Tucker, A. P., gold, Kern County, 259

Tucker, W. B., Sampson, R. J., and Oakeshott, G. B., *Mineral resources of Kern County*, 203-297, pls. 9-18
Tulare County, mineral occurrences: calcite, 523; rhodonite, 530; riebeckite, 522; scheelite, 531
Tungsten Big Lode Mine, Kern County, 275
  Chief mine, Kern County, 275
  Hill mine, Kern County, 275
  , Kern County, 239-241, 271-276
  King mine, Kern County, 275
  Queen mine, Kern County, 276
  , Tuolumne County, 82
Tungstore Mines Co., tungsten, Kern County, 275
Tunneling, in gold mining, 1848-57, S91-93
Tuolumne-Calaveras County marble belt, photo, pl. 7A
Tuolumne County, geography, 48
  , gold, 54-75: east belt, 55-56; Mother Lode, 55; placer mines, 73-75; pocket mines, 56; quartz mines, 56-73; summary, 54-56
  , limestone near Sonora, geology, 509-513, pls. 24, 25
  , map of western, showing mines, pl. 8
  , mineral deposits: chromite, 524; garnet, 525; pitticite, 529; scheelite, 532; scorodite, 532
  mines and mineral resources, 47-83, pls. 4-8: bibliography, 83; gold. 54-75; production 1880-1946, table showing, 50-53
Tuolumne tungsten mine, Tuolumne County, 82
Turnbull oil field, characteristics, 375, 390. 405

U

Ultican, L. L., sand and gravel, Butte County, 439, 453
Ultramarine blue, use in rubber industry, 560
Underground workings, map symbols used by the U. S. Geological Survey, 115
Understock, E. N. and Mattye M.—gold, Butte County, 454
Uncle Sam gold mine, Kern County, 235-236
Union Lime Co., limestone, Kern County, 279
Union Oil Co., Kern County, 289, 290; water-flooding projects, 364-365
United Mines, Inc., gold, Kern County, 255
U. S. Bureau of Mines: exploration of Ione clay deposits, 497; work on Penn mine slag dump, 102-103
U. S. Geological Survey, classification of public lands by, 472-473
U. S. Geological Survey, map symbols used in publications of, 109-116
U. S. Lime Products Corp., Tuolumne County: geologic map of part of limestone mine, pl. 25; limestone production, 79-80; marble quarry site, 77
U. S. limestone consumption for chemical and processing uses, 1921-45, table showing, 320-324
Universal Cons. Oil Co., Kern County, 295
Urbana and Frank gold mine, Kern County, 269
Uren, Lester C., Foreword to "Water-flooding as a method of increasing California oil production," 124-125
Uvarovite, California deposits—see garnet, 525

V

Vallecito and vicinity, sketch map of, S118
Valley View Mining Co., gold, Kern County, 236, 269
Vandergrift, S. A., gold, Butte County, 454
Venas (Venos, Vanos), Lewis (and others), gold, Butte County, 440, 443, 453
Ventura Avenue oil field, characteristics, 377, 392, 407
Venus gold mines, Kern County—see Ederl Mines, Ltd., 257
Venus gold quartz mine, Butte County, 453
Vermont Geological Survey, 315-316
Violarite, San Diego County deposit, 533
Virginia Geological Survey Division, Conservation Commission, 316
Viscosity of oil, important factor in water-flooding, 152-154
Vivianite, Inyo County deposit, 534
Volcanic ash and pumicite deposits, Kern County, 250-251, 279
Volcanics, Sonoma-Oakville district, 35
Voltaite, Sonoma County deposit, 534
Voss, J. D., gold group, Kern County, 256; gold-silver-copper, 255, 269
Vulture patented gold claim, Tuolumne County—see Harvard, 68

W

Walker, George W.; Heyl, George R. and—*Geology of limestone near Gazelle, Siskiyou County, California*, 514-520, pl. 26
  , Joe, gold mine, Kern County, 261
  , Olive A., gold, Butte County, 444, 453
  , W. B., gold, Kern County, 265

Wall Street gold deposit, Kern County, 269
 gold mines group, Kern County, 269
 tungsten group, Kern County—see Tungsten Chief, 275
Walters, J. W., gold, Kern County, 214, 255
Wannasha gold mine, Butte County, 453
Ward, Earl S., gold, Butte County, 444
Warner, Juan Jose, On the discovery of gold in California, 1841, S20
Warner, Merrill, Crowthers—tungsten, Kern County, 274
Warren, Governor Earl—Address to American Inst. Min. and Met. Engrs., Inc., 1949, 499-500
Warrington gold mine, Kern County, 269
Wasco oil field, Kern County: characteristics, 383, 399, 414; production 1940-47, 292
Washington Division of Mines and Geology, 316-317
Wason, Louise M., Burroughs, Chas. S., et al., gold, Butte County, 446
Water, connate, in petroleum reservoirs—relation to water-flooding, 155-156
 -flooding as method of increasing oil production in California, Pt. 1, 123-202; Pt. 2, 363-416; Pt. 3, 541-551
 injection: at Lost Hills, 366-367; pressures in flooding oil wells, 182-184; rates in flooding oil wells, 184-187; source of for flooding oil wells, 156-157
 , mine, Penn mine slag dump, 104-105; sample analysis, 104
 phases in petroleum reservoirs, 155-161
 purification, limestone used in, 330-331
 treatment in petroleum reservoirs with relation to flooding, 157-161
 and oil characteristics and production from California oil fields, 370, 401-415
Waters gold mine, Tuolumne County—see Atlas, 58-59
 , J. E., gold, Kern County, 265
Watkins, W. P., gold, Kern County, 236, 269
Waysalt gold mine, Butte County, 450
Webb, W. S., clay, Kern County, 277
Wedge gold mine, Kern County—see Exposed Treasure, 218, 258
Wedge mercury claim, Napa County—see La Joya Mine, 39
Wedge Extension, Napa County—see La Joya Mine, 39
Wegmann, E. L., gold, Kern County, 227, 262
Weighelt, C., fuller's earth, Kern County, 277
Welbourne, Mrs. J. J., gold, Kern County, 253
Welch gold placer, Butte County, 453
Welch, T. C., and Marsh, H. E., gold, Kern County, 236-237, 270
Wellbaun, Mrs. J. J., gold, Kern County, 253
Wellington, Sidney, gold, Butte County, 450
Wells, John, lead, Butte County, 441
Welsh, T. C., and March, H. E., gold mine, Kern County, 236-237, 270
West Baker borax mine, Kern County, 244
 Branch gold placer, Butte County, 453
 , Mrs. Ella M., and Porter, L. L., gold, Kern County, 235-236, 267
 End gold mine, Kern County—see Big Gold, 254
 Side oil fields, Kern County, production 1940-47, 288-292
 Virginia Geological and Economic Survey, 317
Western Borax mine, Kern County—part of Pacific Coast Borax, 276
Western Geophysical Drilling Co., clay analyses, 498
Western Gulf Oil Co., Kern County, 288, 295
Wheeler Ridge oil field, Kern County: characteristics, 384, 399, 414; production 1940-47, 295
White Bluff clay deposit, Kern County, 277
 Castle pumicite deposit, Kern County, 251, 279
 gold mine, Kern County—see Sidney, 267
 Horse Rand Mining Co., silver, Kern County, 271
 Ridge dolomite mine, Kern County, 278
 Rock magnesite mine, Tuolumne County, 81
 Star gold mine (two), Kern County, 269
 , Stewart Edward, cited, 6
 Swan clay deposit, Kern County, 277
Whiting, limestone in preparation of, 332
Whitlow, Jess, gold, Butte County, 451
Whitmore Mines, Inc., gold, Kern County, 236, 269
Whittier oil field, characteristics, 375, 390, 405
Whitton mercury mine, Napa County—see La Joya, 39-43
Why Not tungsten mine, Kern County—see Buckhorn, 272
Wiebelt, Frank J. and Ricker, Spangler, *Penn mine slag dump and mine water, Calaveras County, California*, 99-105
Wiese, John H.; Heyl, George R. and—*Geology of limestone near Sonora, Tuolumne County, California*, 509-513, pls. 24, 25
Wiggins antimony mine, Kern County, 207, 252
Wilcox Estate, gold, Kern County, 230, 264
Willard Cons. gold quartz mine, Butte County, 453

Willey (?), Harry F., gold, Kern County, 225, 260
William George gold lode, Butte County, 454
Williams clay deposit, Kern County—see Jawbone Canyon, 246, 277
    , L. B., copper-gold-silver, Kern County, 208, 253
    , Nick, Ranch, tungsten mine, Kern County, 276
    , Tom, pumicite deposit, Kern County, 251, 279
Willis, F. A., gold, Butte County, 451
Wilmington oil field, characteristics, 391, 406
Wilson, John, Estate—gold, Kern County, 258
Wilson, P. W., gold, Kern County, 232, 267
Windy gold mine, Kern County, 236-237, 270
Winston, W. B., *Barium*, 85-97
Wisconsin Geological and Natural History Survey, 317
Witherite, description, 87
Wollastonite, Riverside and San Diego County deposits, 534
Wood, O. G., tungsten, Kern County, 272
Woodruff, D. A., gold, Kern County, 265
Woods, Brook (Brooke?), tungsten (two), Kern County, 274
Woodworth, E. F., gold, Butte County, 440
Wyeis, John, gold, Kern County, 214, 254
Wyoming Geological Survey, 317
Wyoming gold mine, Butte County, 432, 454

X

Xanthophyllite, Riverside County deposit, 534

Y

Yankee Bar gold mine, Butte County, 454
Yellow Aster gold mine, Kern County, 237, 270
    Aster Min. & Mill. Co., gold, Kern County, 237, 266, 270
    Aster tungsten mine, Kern County, 276
    Boy gold mine, Kern County, 270
    Channel Mining Co. (?), gold, Kern County, 264
    Dog Extension Mining Co., gold, Kern County, 270
    Dog Mining Co., gold, Kern County, 237-238, 270
    Treasure gold mine, Kern County, 270
Young, Ray: and Hank (Hand?), Ross—gold, Kern County, 232, 267; and Miller, Frank—clay, 277
Yuba Cons. Gold Fields, dredges 1, 2, 3, Butte County, 432-433, 454; photos, pl. 22
Yuba County, scheelite occurrence, 531
Yuba gold placer, Butte County, 454

Z

Zaca Creek oil field, characteristics, 379, 394, 409
Zellner, Bill, tungsten, Kern County, 275
Zenda Gold Mining Co., Kern County, 270
Zeolite, used in zinc recovery at Penn slag dump, Calaveras County, 105
Zig Zag gold quartz deposit, Butte County, 454
Zimmerman, Erle C., *Materials of inorganic mineral origin used in the rubber industry*, 553-561
Zinc hydrosulphite, used for pulping process, 462
    carbonate, use in rubber industry materials, 561
    -copper, Butte County, 421, 425-426, 440
    oxide, use in rubber industry materials: American process, 561; French process, 560-561
    sulfide, use in rubber industry materials, 561
    , summary sheet of methods investigated for recovery of, 105
    yellow, use in rubber industry materials, 561
Zircon, Los Angeles County deposit, 534
Zoisite, Mono County deposit, 534
Zone names and geologic formation used in Kern County oil fields report, 285
Zuck, A. O., and Tillman, W. R., tungsten, Kern County, 274, 275
Zuna copper group, Kern County—see Copperola, 208
Zundra copper group, Kern County, 209; see also Gold Badger, 253

o

99478-M 6-49 2M

PHYSICAL SCIENCES LIBRARY

EXPLANATION

SEDIMENTARY ROCKS

Quaternary

Alluvium and dredged gravel

Unconformity

INTRUSIVE ROCKS

Mesozoic(?)

70 Dikes of hornblende diorite porphyry, fine-grained diorite and granodiorite (Dip shown by arrow)

Granodiorite, including mafic border facies

p Peridotite and serpentine, generally talcose

METAMORPHIC ROCKS

Paleozoic(?)

"Amphibolite" schist, grading southward into mica-amphibole schist and mica feldspar-quartz schist, meta-diorite(?)

ls Crystalline limestone and dolomite

Quartzite, mica schist, and mica-feldspar schist

① Location of sample taken for chemical analysis

Contact (dashed where approximate)

Contact covered by surficial deposits

Arrow shows plunge of lineation

70 70 62 Strike and dip of beds

80 Vertical beds

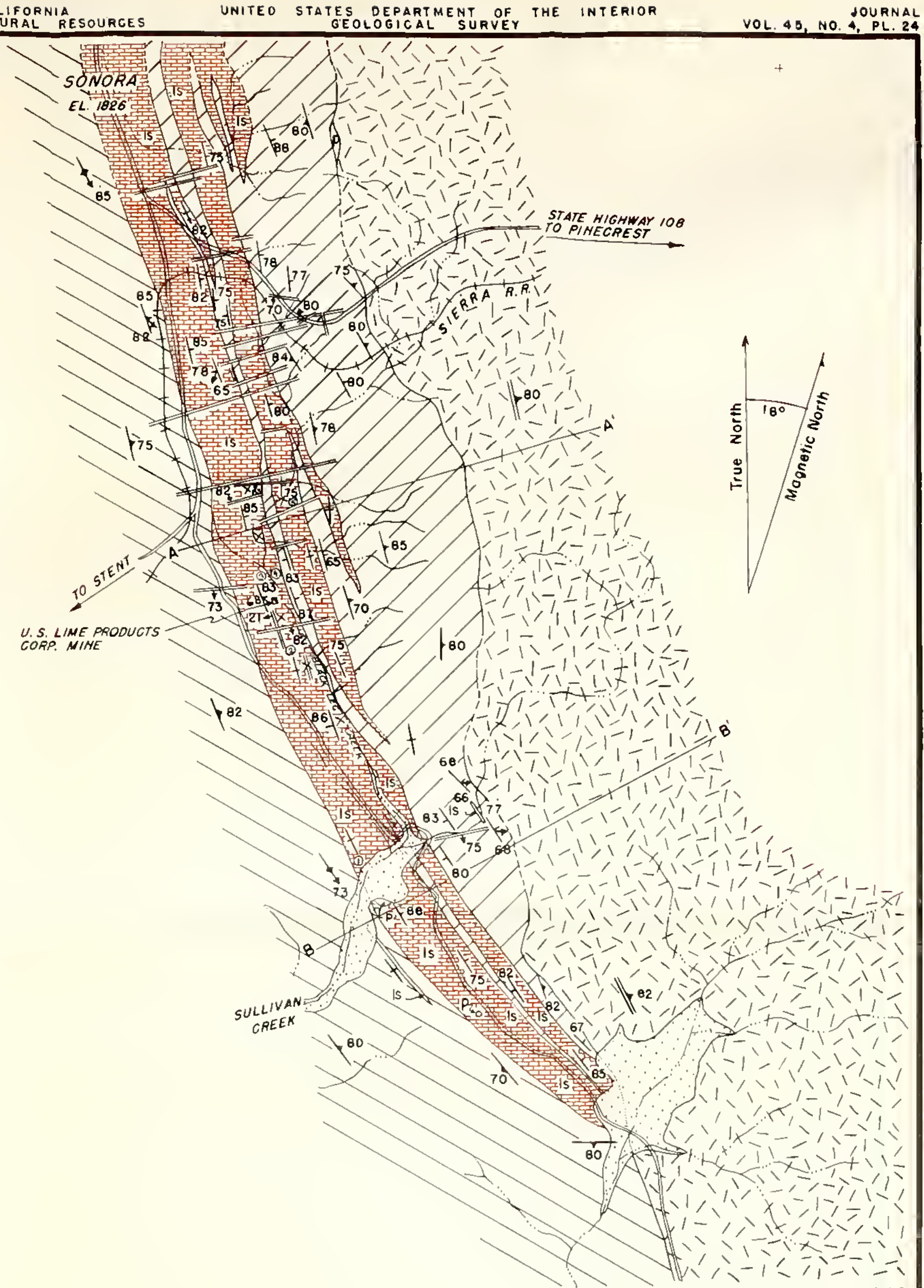
80 72 65 Strike and dip of foliation

80 Vertical foliation

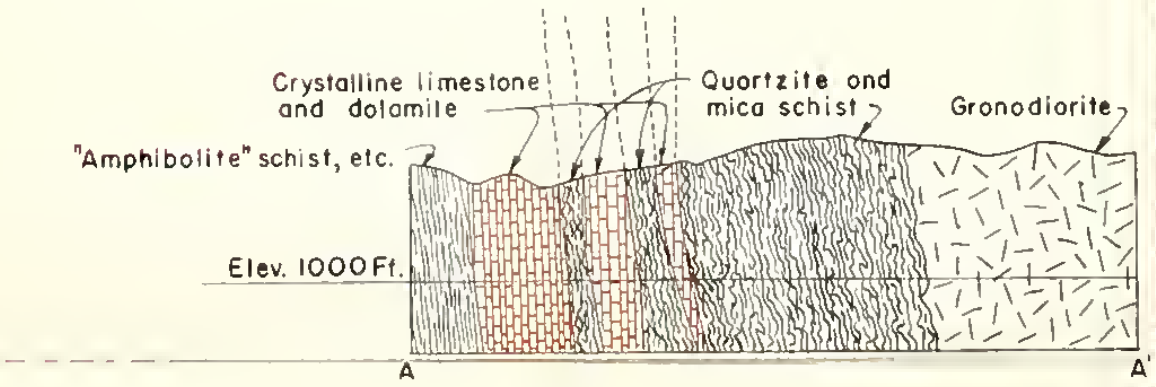
80 Strike and dip of planar structure in granodiorite

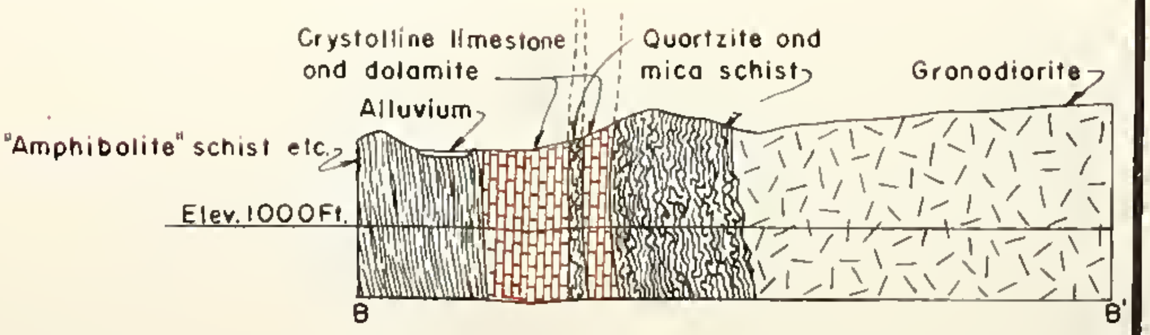
× Quarry in limestone

Vertical shaft of limestone mine



Geology by George R. Heyl, December 1947

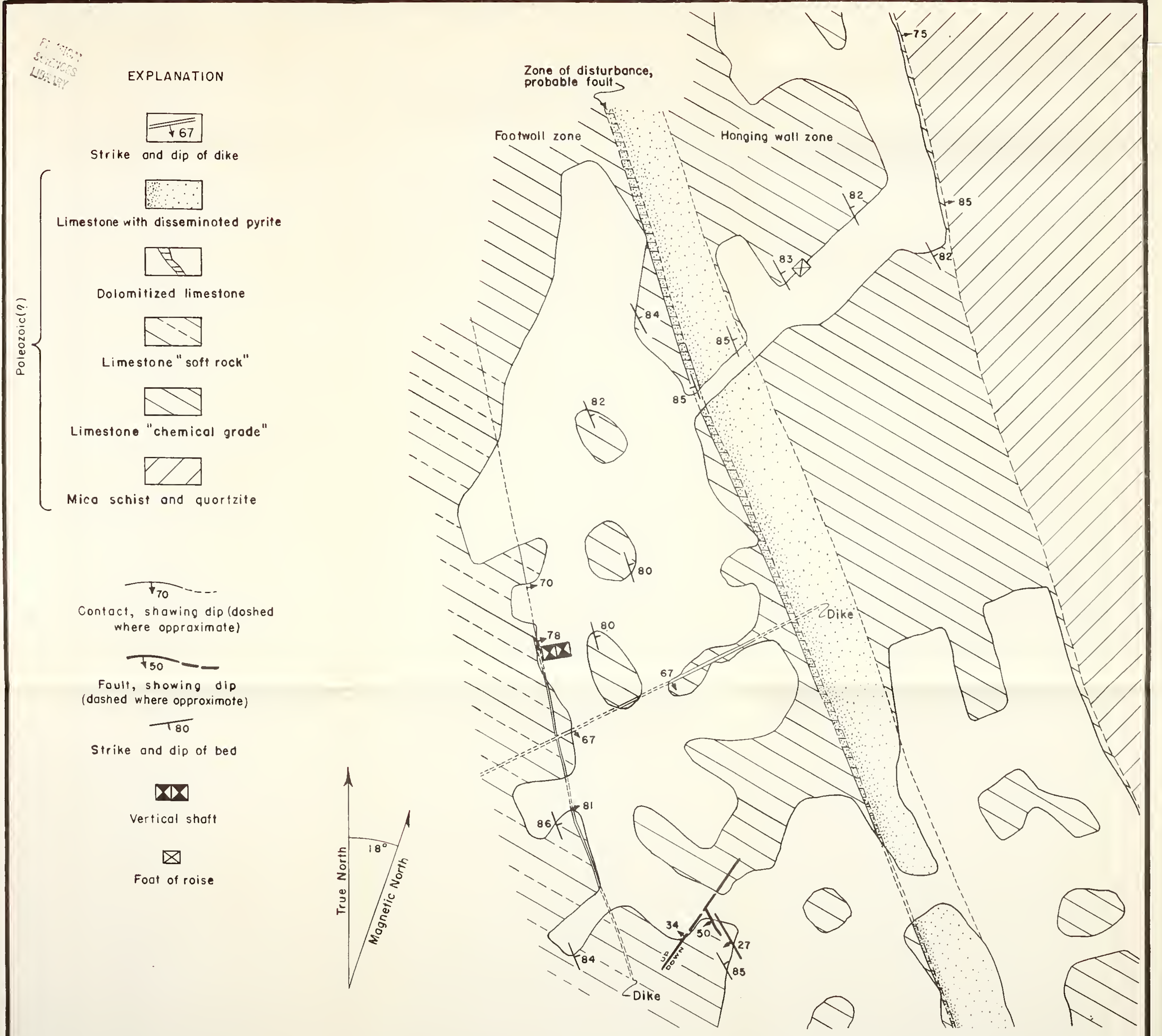

Crystalline limestone and dolomite
Quartzite and mica schist
Granodiorite
"Amphibolite" schist, etc.
Elev. 1000 Ft.
A
A'


Crystalline limestone and dolomite
Quartzite and mica schist
Granodiorite
Alluvium
"Amphibolite" schist etc.
Elev. 1000 Ft.
B
B'

GEOLOGIC MAP AND STRUCTURE SECTIONS OF LIMESTONE DEPOSITS AT BLACK LEG CREEK, SONORA, TUOLUMNE COUNTY, CALIFORNIA

1000 0 1000 2000 3000 4000 FT.

PHYSICAL SCIENCES LIBRARY

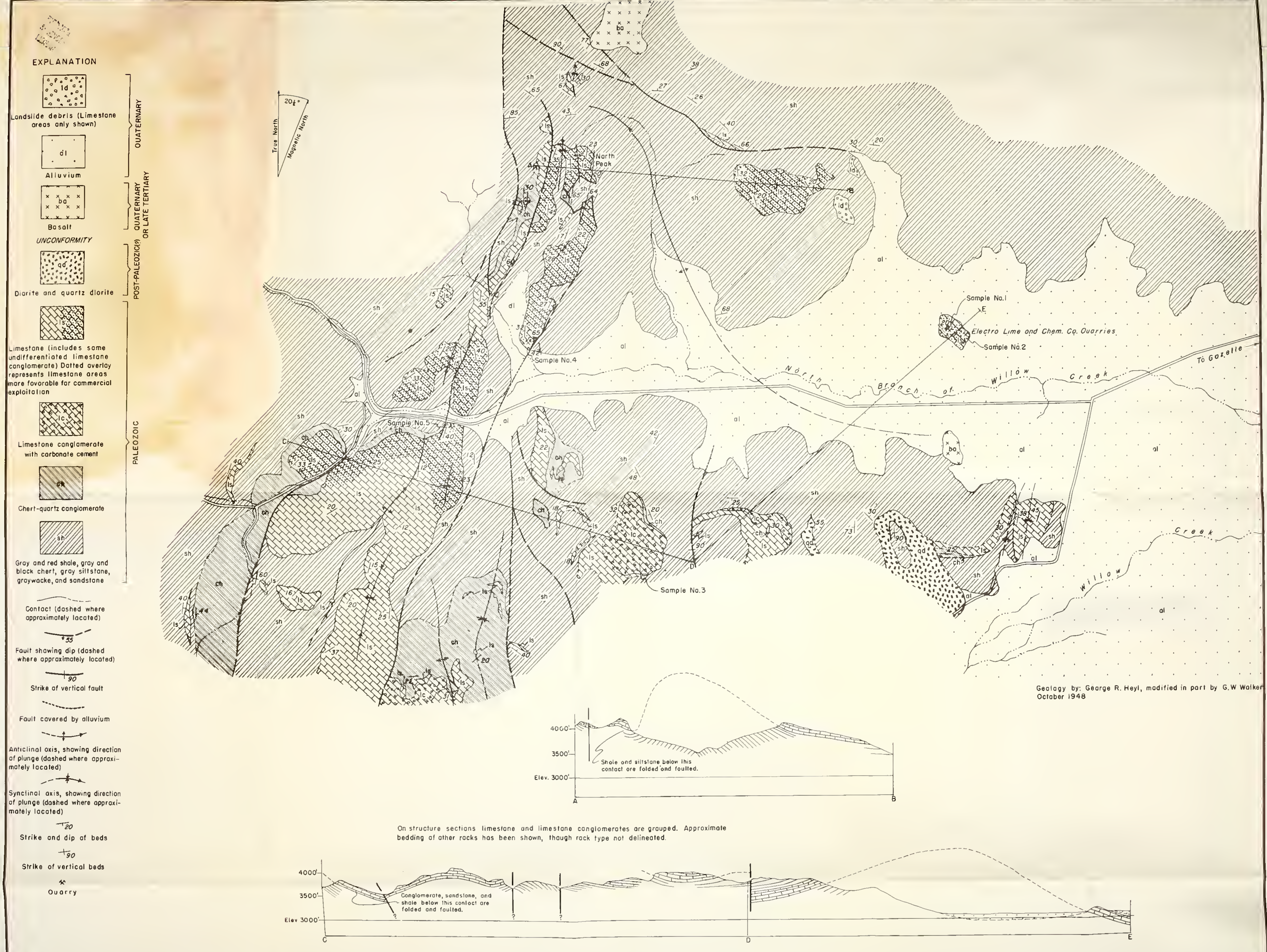


Geology by George R. Heyl, December 1947

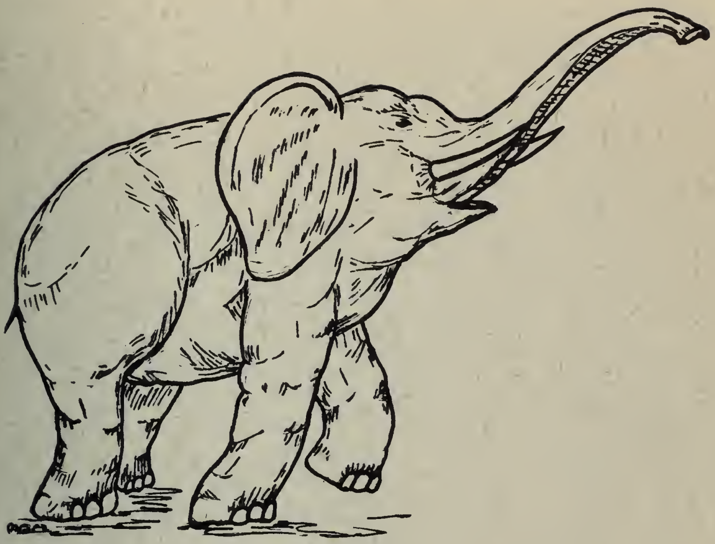
GEOLOGIC MAP OF A PART OF THE 265 LEVEL U.S. LIME PRODUCTS CORPORATION MINE, SONORA, CALIFORNIA

Scale
0 50 100 150 200 Feet

PHYSICAL SCIENCES LIBRARY


EXPLANATION
ld
Landslide debris (Limestone areas only shown)
dl
Alluvium
QUATERNARY
ba
Basalt
QUATERNARY OR LATE TERTIARY
UNCONFORMITY
qd
Diorite and quartz diorite
POST-PALEOZOIC(?)
ls
Limestone (includes some undifferentiated limestone conglomerate) Dotted overlay represents limestone areas more favorable for commercial exploitation
lc
Limestone conglomerate with carbonate cement
ch
Chert-quartz conglomerate
sh
Gray and red shale, gray and black chert, gray siltstone, graywacke, and sandstone
PALEOZOIC
Contact (dashed where approximately located)
55
Fault showing dip (dashed where approximately located)
90
Strike of vertical fault
Fault covered by alluvium
Anticlinal axis, showing direction of plunge (dashed where approximately located)
Synclinal axis, showing direction of plunge (dashed where approximately located)
20
Strike and dip of beds
90
Strike of vertical beds
Quarry
20½°
True North
Magnetic North
North Peak
Sample No.1
Sample No.2
Sample No.3
Sample No.4
Sample No.5
Electro Lime and Chem. Co. Quarries
North Branch of Willow Creek
Willow Creek
To Gazelle
A
B
C
D
E
Geology by: George R. Heyl, modified in part by G.W. Walker
October 1948
4000'
3500'
Elev. 3000'
Shale and siltstone below this contact are folded and faulted.
On structure sections limestone and limestone conglomerates are grouped. Approximate bedding of other rocks has been shown, though rock type not delineated.
Conglomerate, sandstone, and shale below this contact are folded and faulted.
?
Feet 5000
4000
3000
2000
1000
0
1 Mile

GEOLOGIC MAP AND STRUCTURE SECTIONS OF LIMESTONE DEPOSITS NEAR GAZELLE, SISKIYOU COUNTY, CALIFORNIA



THE ELEPHANT
As They Saw It

STATE OF CALIFORNIA
EARL WARREN, Governor

DEPARTMENT OF NATURAL RESOURCES
WARREN T. HANNUM, Director

DIVISION OF MINES
FERRY BUILDING, SAN FRANCISCO 11
OLAF P. JENKINS, Chief

THE ELEPHANT As They Saw It

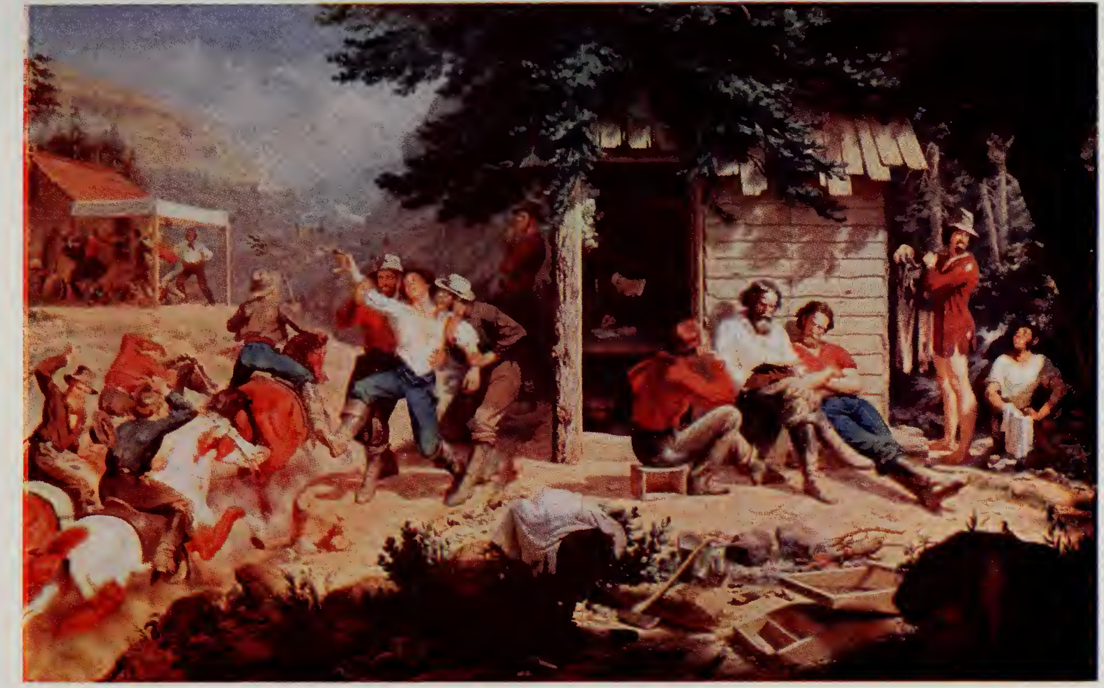
* * * * *

A Collection of Contemporary Pictures and Statements on Gold Mining in California

* * * * *

Assembled by
ELISABETH L. EGENHOFF

As a Centennial Supplement to the
California Journal of Mines and Geology for October 1949



SUNDAY MORNING IN THE MINES

Painted by Charles Christian Nahl about 1870, from sketches and notes made during the gold rush. Picture is on display at the E. B. Crocker Gallery, 216 O Street, Sacramento. Reproduction by courtesy of F. P. Vickery, E. B. Crocker Gallery. Kodachrome by Mike Roberts Studios, Berkeley.

FOREWORD

Much has been written, and is being written, about California's fascinating gold-rush period—its romance and adventure, its morals and lack of morals, and its customs and characters; but comparatively little attention has been devoted to the purpose which most emigrants had in mind when they set out for California: the actual mining of gold.

The series of quotations and pictures presented herein has been gathered to call attention to this phase of the gold-rush, and as a small tribute to those whose efforts a century ago gave purpose to the Centennial we now celebrate; to those who have seen, and still see, "the elephant": to the gold miners of California.

An attempt has been made to trace the history of gold and gold mining in this state from the time, almost four and a half centuries ago, when the legend of the island of California was first conceived, to the year 1860, when the "elephant" was in his vigorous and youthful prime; this, chiefly through the words and drawings of contemporary writers and artists—those who should best know whereof they speak.

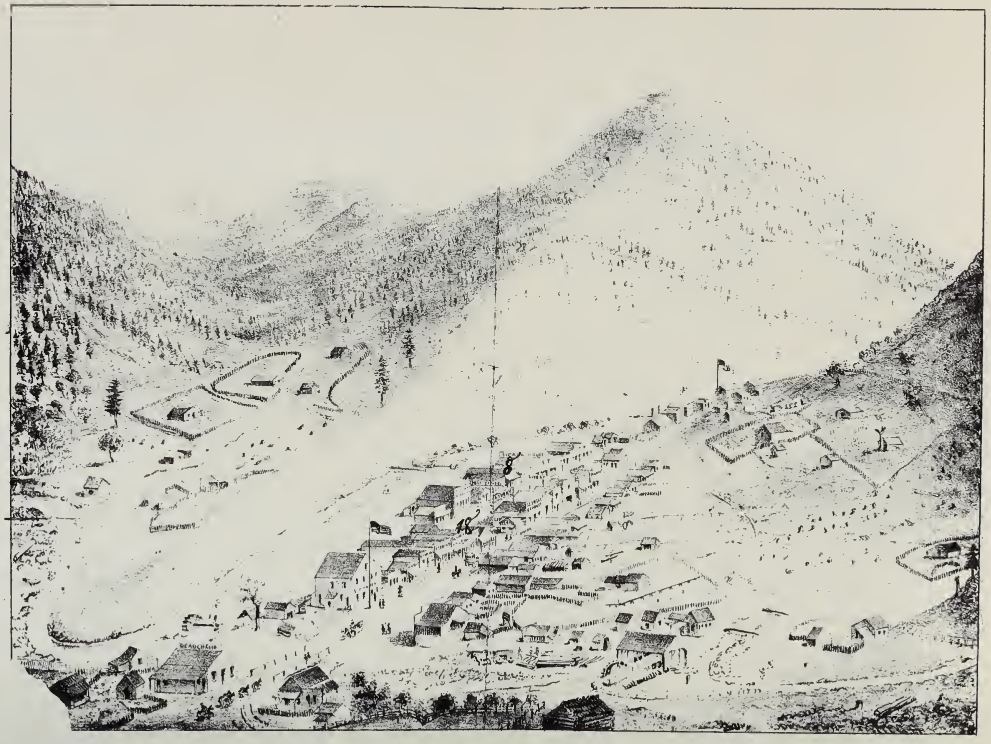
All of the lithographs reproduced in the following pages represent methods of gold mining used in California between 1840 and 1860. Some of the drawings have been published several times—as letterheads in the early days, and as illustrations in articles or books. In each case, the earliest source found has been cited. Captions are those that accompanied the pictures on the letterheads, or in the publications, from which they were obtained.

Comments have been kept to a minimum, and are presented as footnotes supplementing the several quotations.

I should like to express appreciation to Miss Geil Bartels of the California State Division of Mines for her constant assistance in this work; to Miss Mary Helm, Miss Beth Collins and Mr. Henry H. Symons, also of the Division staff; to Miss Ruth Teiser and Miss Geraldine Martino; to Mr. H. P. Davis of Nevada City; to Miss Marguerite L. Sinclair of the Utah State Historical Society; to staff members of the California Historical Society, in particular Mrs. Virginia C. Parker and Mrs. Edna M. Parratt; to Mr. Carroll D. Hall, of Sutter's Fort Historical Museum; and to staff members of the Society of California Pioneers, Wells Fargo Bank & Union Trust Co. History Room, Bancroft Library, and California Section of the California State Library; without whose cooperation and many kindnesses this compilation could not have been made.

San Francisco
May 18, 1949

ELISABETH L. EGENHOFF
Editor, Division of Mines



VIEW OF GOODYEARS BAR & GOODYEARS CREEK, SIERRA CO., CALA. WITH MONTE-CRISTO IN THE DISTANCE. Drawn by Wm. B. Monmonier, Goodyears Bar, Sierra County; lithy. of Britton & Rey, S. F. Original lithograph donated to the collection of the California State Division of Mines by Miss Louisa F. Curieux, Oakland.

CONTENTS

Page

FACTS AND FANCIES, 1500-1840 7

- Garcí Ordóñez de Montalvo, on the golden "island," California, 1510 9
- Hernando Cortés to Charles V, Holy Roman Emperor and King of Spain, 1524 10
- Richard Hakluyt, on the voyage of Sir Francis Drake to New Albion, 1579 11
- Richard Hakluyt, on the rich isles of California, 1597 12
- Juan José Pico, on rumors of gold before 1840 13
- William Heath Davis, on gold in the Sacramento Valley, 1843-44 14
- John Bidwell, on exploration for gold in California, 1844-45 15

THE GOLD RUSH OF 1842 17

- John Bidwell, on the discovery of gold in California, 1841 19
- Juan José Warner, on the discovery of gold in California, 1841 20
- Abel Stearns, on the discovery of gold in California, 1842 21
- Thomas O. Larkin, to the Editor of the New York Sun, 1846 23

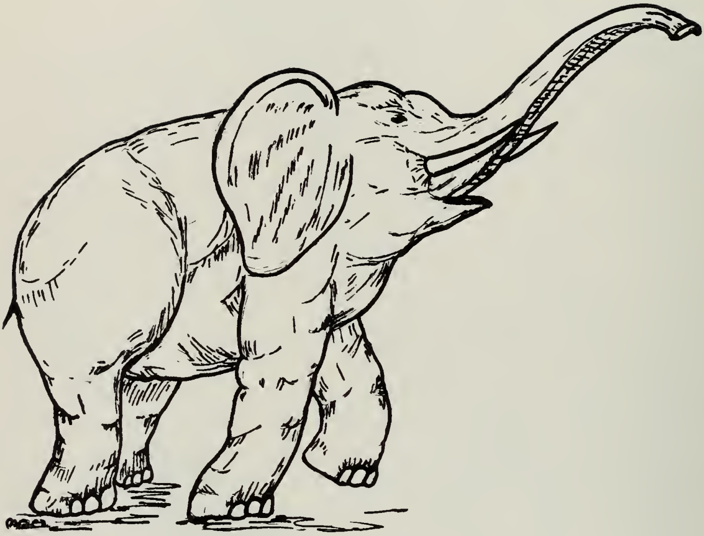
THE DISCOVERY OF GOLD AT SUTTER'S MILL AND EARLY DAYS OF THE GOLD RUSH, JANUARY 24, 1848 TO AUGUST 23, 1848 25

- James W. Marshall, to J. M. Hutchings, on the discovery of gold January 24, 1848 27
- The discovery of gold as recorded in the diary of Henry W. Bigler, January 24, 1848 31
- The discovery of gold as recorded in the diary of Azariah Smith, January 30, 1848 31
- John A. Sutter, to J. M. Hutchings, on the discovery of gold, January 24, 1848 34
- John Bidwell, on the discovery of gold, January 1848 39
- Thomas O. Larkin, to James Buchanan, June 1, 1848 41
- Thomas O. Larkin, to James Buchanan, June 28, 1848 43
- Joseph L. Folsom, on Marshall's first flake of gold, August 23, 1848 49
- Colonel R. B. Mason, to General R. Jones, August 17, 1848 50

THE MINING OF GOLD, 1849-1860 59

- J. Wesley Jones' Pantoscope 61
- J. D. Borthwick "sees the elephant" 63
- Mining for gold in California 79
  - The long tom 87
  - Sluicing 89
  - Ground sluicing 89
  - Sinking a shaft 91
  - Tunneling 91
  - Fluming 93
  - The hydraulic method of working 95
  - River mining 97
  - Quartz mining in California 101

DAGUERREOTYPES AND AMBROTYPES TAKEN IN THE DIGGINGS 117



"This animal stood symbolically for the whole business of gold seeking. When a San Franciscan told a friend that he'd about decided to 'see the elephant', he did not mean that he was going on a toot, but that he intended to take a flier at the mines." Stewart Edward White.*

---

* After Old California, In Picture and Story, by Stewart Edward White, New York, Garden City Publishing Co., Inc., 1939.

FACTS AND FANCIES
1500-1840

GARCÍ ORDÓÑEZ DE MONTALVO

On the Golden "Island," California—1510

. . . Sabed que á la diestra mano de las Indias hubo una isla, llamada California, muy llegada á la parte del Paraíso Terrenal, la cual fué poblada de mujeres negras, sin que algun varon entre ellas hubiese, que casi como las amazonas era su estilo de vivir. Estas eran de valientes cuerpos y esforzados y ardientes corazones y de grandes fuerzas; la ínsula en si la mas fuerte de riscos y bravas peñas que el mundo se hallaba; las sus armas eran todas de oro, y tambien las guarniciones de las bestias fieras, en que, despues de las haber amansado, cabalgaban; que en toda la isla no habia otro metal alguno. . . .

En esta isla, California llamada, habia muchos grifos, por la grande aspereza de la tierra y por las infinitas salvajinas que en ella habitaban, los cuales en ninguna parte del mundo eran hallados; y en el tiempo que tenian hijos, iban estas mujeres con artificios para los tomar, cubiertas todas de muy gruesos cueros, y traíanlos a sus cuevas, y allí los criaban. Y siendo ya igualados, cebábanlos en aquellos hombres y en los niños que parian, tantas veces y con tales artes, que muy bien conocian á ellas, y no les hacian ningun mal. Cualquiera varon que en la isla entrase, luego por ellos era muerto y comido; y aunque hartos estuviesen, no dejaban por eso de los tomar y alzarlos arriba, volando por el aire, y cuando se enojaban de los traer, dejábanlos caer donde luego eran muertos.[*]

---

[*] In these words by the soldier-author Garcí Ordóñez de Montalvo, purveyor of adventure and romance, the legend of California, the golden legend, was conceived. The novel in which they appeared, *Las Sergas de Esplandián*, was written, some believe, before the discovery of America. It was published in Toledo, Spain, about 1510.

"Know that on the right hand of the Indies there is an island called California, very near to the terrestrial paradise, which was peopled with black women without any men among them, because they were accustomed to live after the fashion of amazons. They were of strong and hardened bodies, of ardent courage and of great force. The island was the strongest in the world from its steep rocks and great cliffs. Their arms were all of gold, and so were the caparisons of the wild beasts which they rode after having tamed them; for in all the island there is no other metal. . . . In this island, called California, there were many griffins, on account of the great ruggedness of the country, and its infinite host of wild beasts, such as never were seen in any other part of the world; and when these griffins were yet small, the women went out with traps to take them, they covered themselves over with very thick hides, and when they had caught the little griffins they took them to their caves, and brought them up there. And being themselves quite a match for the griffins, they fed them with the men whom they took prisoners, and with the boys to whom they gave birth, and brought them up with such arts that they got much good from them, and no harm. Every man who landed on the island was immediately devoured by these griffins; and although they had had enough, none the less they would seize them, and carry them high up in the air in their flight; and when they were tired of carrying them, would let them fall anywhere as soon as they died." *Don Pascual de Gayangos ed., 1880; Edward Everett Hale, trans.*

HERNANDO CORTÉS

To Charles V, Holy Roman Emperor and King of Spain—1524 *

. . . y assimismo me trujo relacion de los señores de la provincia de Ciguatan, que se afirman mucho haber una isla toda poblada de mugeres, sin varon ninguno; y que en ciertos tiempos van de la tierra-firma hombres, con los quales han aceso; y las que quedan preñadas, si paran mugeres las guardan, y si hombres los echan de su compania; y que esta isla está diez jornadas de esta provincia; y que muchos de ellos han ido allá y la han visto. Dicenme assimismo que es muy rica de perlas y oro; yo trabajaré en teniendo aparejo de saber la verdad y hacer de ello larga relacion á vuestra magestad.

---

* This account, transmitted by Hernando Cortés, adventurer, explorer, and conqueror of Mexico, appeared in the *Carta Quarta de Relacion,* dated October 15, 1524, a little more than a decade after the publication of *Las Sergas de Esplandián.* Ten years later, in 1534, Fortuño Ximenes, fleeing from the penalty for mutiny—he had murdered the ship's captain and set a part of the company ashore—sailed northwest from the Mexican coast into unknown waters, and came upon the peninsula now known as Lower California. Ximenes and twenty others were killed by natives when they went ashore; but some of the party escaped and returned to Mexico with reports of the discovery of an "island" rich in pearls, and well populated. The next year, 1535, Cortés himself landed on the peninsula; he is the one who is said to have christened the new land—with more charity than hope—California.

"He also conveyed to me an account of the men of the province of Ciguatan, who affirm that there is an island entirely populated by women, without a single man; and that at certain times men go to the island from the mainland; if the ensuing children are girls, they are taken care of, but if they are boys, they are rejected; and that this island is a ten-day journey from this province; and that many of them have gone there, and have seen it. They tell me, likewise, that it is very rich in pearls and gold; I will endeavor to learn the truth and to relate it to your majesty at length." *After T. H. Hittell, History of California, 1885; G. Martino, trans.*

RICHARD HAKLUYT

On the Voyage of Sir Francis Drake to New Albion—1579 *

Our Generall called this Countrey *Noua Albion,* and that for two causes: the one, in respect of the white bankes and cliffes, which ly toward the sea: and the other, because it might haue some affinitie with our countrey in name, which sometimes was so called.

There is no part of earth here to bee taken up wherein there is not a reasonable quantitie of gold or siluer.

At our departure hence our Generall set up a monument of our being there, as also of her Maiesties right and title to the same, namely a plate, nailed upon a faire great poste, whereupon was ingrauen her Maiesties name, the day and yeere of our arriuall there, with the free giuing up of the prouince and people into her Maiesties hands, together with her highnes picture and armes, in a peece of sixe pence of currant English money under the plate, where under was also written the name of our Generall.

---

* This quotation concerning Sir Francis Drake's expedition which touched the shores of California (New Albion) in 1579, is drawn from *The famous voyage of Sir Francis Drake into the South Sea and there hence about the whole Globe of the Earth, begun in the yeere of our Lord, 1577,* published in *Principal nauigations, voiages, and discoueries of the English nation, Anno Dom. 1589,* by Richard Hakluyt. A very similar account of the voyage was published as *The World Encompassed,* by Sir Francis Drake, nephew of the great navigator; it was taken from the Journal kept by Francis Fletcher, chaplain of the expedition.

RICHARD HAKLUYT

On the Rich Isles of California—1597 *

An extract of a Spanish letter written from Pueblo de los Angeles in Nueua Espanna in October 1597 touching the discouerie of the rich Isles of California, being distant eight dayes sayling from the maine.

We have seene a letter written the eight of October 1597, out of a towne called Pueblo de los Angeles situate eighteene leagues frõ Mexico, making mention of the Ilands of California situate two or three hundreth leagues frõ the maine land of Nueua Espanna, in Mar del Sur: as that thither haue bene sent before that time some people to conquer them: which with losse of some twentie men were forced backe. After that they had wel visited and found those Islands or countreys to be very rich of gold and siluer mynes, and of very fayre Orientall pearles, which were caught in good quantitie upon one fathome and an halfe passing in beautie the pearles of the Island Margarita: the report thereof caused the Vic-roy of Mexico to send a citizen of Mexico with two hundreth men to conquer the same. Therein also was affirmed that within eight dayes they could sayle thither from the mayne.

---

* From *The third and last volume of the voyages, nauigations, traffiques, and discoueries of the English Nation, collected by Richard Hakluyt, Preacher and sometimes student of Christ-Church in Oxford: Imprinted at London by George Bishop, Ralfe Newberie, and Robert Barker, Anno Dom. 1600.*

For more than two hundred years thereafter, the world was apparently not much concerned with California's rumored wealth, though there are some indications that glimpses of her treasure may have been revealed to early settlers, early in the nineteenth century.

JUAN JOSÉ PICO

On Rumors of Gold Before 1840 *

El P. Martinez, á nuestro paso por su mision no nos habló nada de revolucion contra el gobo.—Si nos facilitó viveres y cuantos recussor necesitámos hasta ropa para los soldados, y á vanos de nosotros nos diá oro—á mi, á Raimundo y Gabriel de la Torre y Franco. Solo nos regaló como 20 onzas de oro, no acunadas sino en bolitas de á onza, porque nos queria mucho por haber sido nosotros discipulos de él, y ayudadores de misa aqui en la mision, en donde aprendimos á cantar música de iglesia. Los dos hermanos Raimundo y Gabriel y yo habiamos estado con el Padre . . . de un año ántes de que entrásemos á soldados. Eso oro de que hago mencion creia deba haber sido recogido en el punto de San José cerca de la mision. Había entónces, siendo nosotros muchachitos, como 12 españoles trabajando dentro del cuadro de la mision, creo que limpiando plata y oro porque tenía el Padre muchos botes de azoqué e instrumentos y materiales para limpiar esos metalos. Sé que . . . muchas veces entrar á ver lo que hacian, y nunca nos permitiéron—solo dejaban entrar algun alcade indios bajo penas severas si divulgaba algun secreto.

---

* From *Acontecimientos en California de que hace memoria Don José de Jesus Pico, Capitan que fué de milicias auxiliaries, dictatos á Thomas Savage en San Luis Obispo, 1878.* Published from manuscript by courtesy of Bancroft Library, University of California, Berkeley.

"Father Martinez, at the time we were at his mission said nothing to us about revolution against the government. He gave us provisions and whatever else we needed, even to clothes for the soldiers, and he gave us gold—to me, to Raimundo and Gabriel de la Torre and Franco. He only gave us about twenty ounces of gold, not coined, but in little balls of an ounce, because he liked us very much because we had been his pupils and assisted him at mass here in the mission, where we learned to sing church music. The two brothers, Raimundo and Gabriel, and I had been with Father a year before becoming soldiers. This gold that I mention I believe to have been gathered at the point of San Jose near the mission. There were, when we were little children, about twelve Spaniards working within the Mission square; I believe that they were cleaning silver and gold because the Father had many flasks of quicksilver and instruments and materials with which to clean these metals. I know many times we tried to enter to see what they were doing, and they never permitted us to; only Indian alcaldes, under penalty of severe punishment if they revealed any secret, were allowed." *G. Martino, trans.*

WILLIAM HEATH DAVIS

On Gold in the Sacramento Valley—1843-44 *

Father Muro, while I was visiting him along in 1843 or 1844, at the time I was agent of Paty, McKinlay & Co. at Yerba Buena, mentioned to me his knowledge of the existence of gold in the Sacramento valley as a great secret, requiring me to promise not to divulge it. I have never mentioned it to this day to anyone. Afterward, in conversation with Father Mercado, the same subject was gradually and cautiously broached, and he confided to me his knowledge of the existence of gold in the same locality. Both of the priests stated that their information was obtained from Indians. . . . After he had imparted the news of gold in the Sacramento valley, I would interrupt the discourse, and, for the sake of argument, suggest that it would be better to make the matter known, to induce Americans and others to come here, urging that with their enterprise and skill, they would rapidly open and develop the country, build towns and engage in numberless undertakings which would tend to the enrichment and prosperity of the country, increase the value of lands, enhance the price of cattle, and benefit the people. He would answer that immigration would be dangerous; that they would pour in by thousands and overrun the country; the work of the missions would be interfered with, and as the Californians had no means of defense, no navy or army, the Americans would soon obtain supreme control; that they would undoubtedly at some time come in force, and all this would happen; but if no inducements were offered, the change might not take place in his time.

---

* This report of his conversations with Father Muro of San Jose Mission and Father Mercado of Santa Clara Mission, may be found in William Heath Davis' *Sixty Years in California*, A. J. Leary, Publisher, San Francisco, 1889.

Juan B. Alvarado, governor of California from 1836 to 1842, believed the Russians knew of gold in the Sacramento Valley as early as 1814, for in that year a Russian jailed at Monterey was found to have gold in his possession. He would not reveal its source, however. Alvarado also stated that the rings used at his wedding in August 1831 were made of California gold; and that the Californians "knew of the existence of gold deposits on the slopes of the northern mountains, but the Indians who were so much more numerous than we, prevented our exploring in that direction." General M. G. Vallejo likewise indicated that the Californians knew of the presence of gold, but that because of the Indians they could not make use of that knowledge.

JOHN BIDWELL

On Exploration for Gold in California—1844-45 *

Another incident I may mention. There arrived on this coast a certain Dr. Sandels a scientific gentleman. He was a Swede by birth but educated in London. . . . On his arrival at Sutter's the latter said one day "Dr. cant you find me a gold mine?" His reply was Capt. S. never think of gold mining. Your best mine is in the soil. The Doctor came as far north as Chico Creek with Mr. Dicky but did not examine the mountains except the Buttes. On his return he told Sutter that there were indications of gold but that unless the mountains on the sides were richer than those in the valley the mines would not pay to work.

Early in the spring of 1844 while I was still in charge of Sutter's Hock Farm and shortly after Fremont had set out on his return to the East a Mexican in Sutter's employ by the name of Pablo Gutierez having occasion to go the mountains on Bear River reported to me that he knew there was gold from indications which he had seen. This man had worked in placer mines in Mexico. In a few days he and I went to the place. He pointed out to me the signs and was very positive that gold was there. These signs consisted of coarse black sand quartz-rock etc. in the channel of a gulch then dry but which had been swoolen in the winter. But in order to make the discovery, he required he said a Battea. His description of the needed article was reitterated in so many ways and with such particularity that it seemed something very hard to make. It could not be made in California. He could get it by going to Mexico and at first that was the plan but subsequently the plan was changed and he was to go with me as soon as we could earn the means around Cape Horn to Boston where I could interpret and explain just how to make a Battea. In the meantime he was to say nothing about gold being there to any person else, and I believe he kept his promise. Now this Battea spoken of was nothing more or less than—with the Mexicans—the indispensible wooden bowl. At the beginning of the war of 1844 and 45 Gutierez being from Mexico was faithful to the Mexican cause. Sutter sent him twice with dispatches to Gov. M. The latter time in the vicinity of the town of Gilroy, he was taken prisoner by Castro, or his men, and hung.

. . . In July, 1845 I went into the Sierra Nevadas ostensibly for the purpose of giving directions to men sawing lumber for Sutter—with whip saws—but with the real purpose of examining the region for gold. Pablo Gutierez being dead the plan of going to Boston of course was given up. I had a little knowledge and precious little too about gold mining by my visit that spring to the gold mines near San Fernando.

But I wished to make an effort to verify Gutierez's supposition as to gold in the Sierra Nevadas, but the experiment if then made had to be further south and near where the men were sawing lumber.

Starting early in the morning I reached the place about forty miles from Sutter's Fort, at one p.m. In the afternoon while the men were at work in another direction I stole away unbeknown to them toward a deep valley traversed by a small stream to the south. When half way or more, the intense heat and the probability of finding no water in the stream and possibly my impression of gold mining as gained near San Fernando had the effect to make me change my purpose.

---

* From *California, 1841-8, An immigrant's recollections of a trip across the plains and of men and events in early days, including the Bear Flag revolution, by John Bidwell of Chico—written at the author's dictation by S. S. Boynton for the Bancroft Library, 1877.* Published from manuscript by courtesy of Bancroft Library, University of California, Berkeley, California.

I returned, and after resting awhile mounted my mule—a famous animal of Sutter's, and returned to Sutter's Fort that night, reaching there about midnight.

This same point I visited in the spring of 1849 after I had worked a year at gold mining on Feather River. Miners were at work in nearly all the gulches in that region. The one lying to the south of the ridge where the old saw-pits were had been one of the richest of the very rich gulches in that vicinity.

One man whom I knew—Thomas Fallon of San Jose—told me that had I pulled up a bunch of grass on the margin of the stream and shaken the earth into a pan and washed it, I would in all probability have gotten the color.

THE GOLD RUSH OF 1842

JOHN BIDWELL

On the Discovery of Gold in California—1841 *

The first gold discovered in California so far as I know was made in 1841 by Jean Baptiste Reuelle † at a place in the mountains about thirty miles northeast from the Mission of San Fernando. Jean Reulle was a Canadian but had lived in New Mexico and worked in placer mines there. His discovery of gold in Cal. created no astonishment or excitement whatever owing to the fact no doubt of the very small yield. When I visited the mines at that place in 1845 there were probably about thirty people, most if not all from New Mexico. The average earnings as I learned were very small not exceeding twenty-five cents a day, though at times nuggets had been found occasionally of all sizes up to an ounce.

Though the mine had been worked for nearly four years and consisted of a bank of gravel the progress was very slow and the cut washed into the hill did not exceed thirty feet. An old and wise-looking patriarch of a miner whom all seemed to venerate had more to say than all the rest. He was scraping the ground out with a scoop or spoon made from a bullock horn. He was so knowing that he could tell the ground that contained gold from that did not. As for myself I could see no difference, but he would select the good gravel and put it into the basket and reject the poor. In the course of half an hour or so interrupted frequently by stopping to light the everlasting cigarite, a basket would be filled and put on a platform. This was made to represent a table with a table-cloth on by driving posts into the ground about three feet high and laying poles across in place of plank and leveling it with a little grass and covering it with cotton cloth. The platform was about eight feet long and three or four feet wide. The earth to be washed was piled up in the center after four or five bushels of the golden earth had been selected by the wisdom of the old man and in the manner I have described and then washing began. From a pool about six feet from the platform water was thrown with a basket upon the pile of earth. The muddy water ran off the table lessening by degrees the size of the pile. But the manner of using the water required much skill. The old man would become almost frantic when it was thrown too fast and would seize the basket to exemplify his skill which the others must imitate. After some time the golden earth was so far reduced that the gravel could be taken with the hand and thrown off. The skilled miner not unfrequently turning the stones all over and looking on any side to be certain that no gold adhered to them.

It took an hour or two to finish a washing of this kind. The gold, if any, would be found in small quantities adhering to the cloth after the earth and gravel had been thus removed. The precious metal was then carefully picked up and put in a quill.

I learned of the existence of that mine by seeing some of the gold in Los Angelos in the spring of 1845 at the time of the defeat and capitulation of Governor Micheltorena.

---

* From *California, 1841-8, An immigrant's recollections of a trip across the plains and of men and events in early days, including the Bear Flag revolution, by John Bidwell of Chico—written at the author's dictation by S. S. Boynton for the Bancroft Library, 1877*. Published from manuscript, by courtesy of Bancroft Library, University of California, Berkeley, California.

†According to Ygnacio del Valle (see J. J. Warner's *Historical Sketch of Los Angeles County*) and Abel Stearns, the discovery was made by Francisco Lopez.

JUAN JOSÉ WARNER

On the Discovery of Gold in California—1841 *

While statements respecting the existence of gold in the earth of California, and its procurement therefrom have been made and published as historical facts, carrying back the date of the knowledge of the auriferous character of this State as far as the time of the visit of Sir Francis Drake to this coast, there is no evidence to be found, in the written or oral history of the missions, the acts and correspondence of the civil or military officers, or in the unwritten and traditional history of Upper California, that the existence of gold, either with ores or in its virgin state, was ever suspected by any inhabitant of California previous to eighteen hundred and forty-one; and, furthermore, there is conclusive testimony that the first known grain of native gold dust was found upon or near the San Francisco Ranch, about forty-five miles westerly from Los Angeles City, in the month of June, 1841 [by Francisco Lopez]. This discovery consisted of grain gold fields—known as placer mines—and the auriferous fields, discovered in that year, embraced the greater part of the country drained by the Santa Clara River, from a point some fifteen or twenty miles from its mouth to its sources, and easterly beyond them to Mount San Bernardino.

* * * * *

After the preceding pages were printed, copies of the letters were received. A discrepancy in the date of the discovery as related by Mr. Stearns and that given in these pages will be observed. We believe, however, that the date given by us is the correct one, as, among the many authorities for that date is Don Ygnacio del Valle of Camulos, an intelligent and educated gentleman, a man of careful habits, and whose practice has been to make and preserve notes of the events of his life. In the year of the discovery of these gold fields Mr. Valle was appointed an auxiliary Alcalde, expressly for that mining district, and is less likely to be mistaken than Mr. Stearns when writing upon the subject after a lapse of twenty-five years, and who being a merchant at that time, would upon referring to his books, be more likely to find the date of the purchase of the gold, than that of the discovery of the gold fields.

---

* From *An historical sketch of Los Angeles County, California, from the Spanish occupancy, by the founding of the Mission San Gabriel Archangel, September 8, 1771 to July 4, 1876*, by Juan José Warner, published by Louis Levin & Co., Los Angeles: Mirror Printing, Ruling and Binding House, 1876.

The letters referred to in this quotation are those from Abel Stearns to the Society of Pioneers, and from Alfred Robinson to Abel Stearns, which follow.

ABEL STEARNS

On the Discovery of Gold in California—1842 *

LOS ANGELES, July 8th, 1867

Louis R. Lull, Esq., Secretary of the Society of Pioneers, San Francisco

SIR:—On my arrival here from San Francisco, some days since, I received your letter of June 3d last past, requesting the certificate of assay of gold sent by me to the Mint at Philadelphia in 1842. I find by referring to my old account books that November 22d, 1842, I sent by Alfred Robinson, Esq., (who returned from California to the States by the way of Mexico,) twenty ounces California weight (18¾ ounces Mint weight) of placer gold, to be forwarded by him to the U.S. Mint at Philadelphia for assay.

In his letter to me, dated August 6th, 1843, you will find a copy from the Mint assay of the gold, which letter I herewith enclose to you to be placed in the archives of the Society.

The placer mines from which this gold was taken were first discovered by Francisco Lopez, a native of California, in the month of March, 1842, at a place called San Francisquito, about thirty-five miles north-west from this city (Los Angeles).

The circumstances of the discovery by Lopez, as related by him, are as follows: Lopez, with a companion, was out in search of some stray horses, and about midday they stopped under some trees and tied their horses out to feed, they resting under the shade; when Lopez with his sheath knife dug up some wild onions, and in the dirt discovered a piece of gold, and searching further found some more. He brought these to town, and showed them to his friends, who at once declared there must be a placer of gold. This news being circulated, numbers of the citizens went to the place and commenced prospecting in the neighborhood, and found it to be a fact that there was a placer of gold. After being satisfied most persons returned; some remained, particularly Sonorenses (Sonorians), who were accustomed to work in placers. They met with good success.

From this time the placers were worked with more or less success, and principally by Sonorenses (Sonorians), until the latter part of 1846, when most of the Sonorenses left with Captain Flores for Sonora.

While worked there was some six or eight thousand dollars taken out per annum.

Very respectfully yours,

ABEL STEARNS.

New York, August 6th, 1843.

My Dear D. Abel:—I embrace this opportunity of the sailing of a ship from Boston to address you a few lines, and therein to inform you of the result of Your shipment of Gold, which is as follows, as per statement from the Mint at Philadelphia:

"Memorandum of gold bullion deposited the 8th day of July, 1843, at the mint of the United States at Philadelphia, by Grant & Stone, of weight and value as follows:

"Before melting, 18-34/100 oz.; after melting, 18-1/100 oz.; fineness, 926-1,000; value $344.75; deduct expenses, sending to Philadelphia and agency there, $4.02; net, $340.73." . . .

Robinson

---

[*] After Warner, Juan José, *An historical sketch of Los Angeles County, California*, 1876.

In 1845, documents by Manuel Castañares, representative in Congress from the department of Upper and Lower California, were published in Mexico; in these, reference was made to the existence of gold in that department. The translation that follows is from Yale, Gregory, *Legal titles to mining claims and water rights in California under the mining law of Congress of July 1866*, Appendix D, pp. 403-404, San Francisco, A. Roman & Co., 1867:

> "The mining interest in California is of great importance, and I have the satisfaction of assuring you that it forms one of the most valuable resources of that department. Besides the silver mines which are found there, and various other mines which have actually yielded metals, the *gold placer*, especially, is worthy of great attention, which extending nearly thirty leagues, was discovered lately, together with mines of mineral coal. It is painful for me to have to confess that mining is in a worse state than agriculture: the latter is in its infancy; the former, it can be said, is not yet born, notwithstanding that, according to the nearest estimate of reliable persons in Los Angeles, on my departure from that town, in December, 1843, there were in circulation about two thousand ounces of gold which had been extracted from the above-mentioned placer, the greater part of it destined to go to the United States. This metal contains, according to the certificate of its assay by the mint of this capital, which I sent to the Government at the beginning of this year, *twenty-two carats two and a half grains of gold, fifteen grains of silver. September 1st, 1844.*"

THOMAS O. LARKIN

To the Editor of the New York Sun—1846 *

CALIFORNIA 30th June 1846

Editor New York Sun
SIR:

By your paper and a few others that occasionally reach the Farest West, I find Texas has had her day & say. Origon is having hers—& California is to have, and that before Mr. Polk's present term expires. By the way—the Mexicans and Californins on reading Mr. Polk Annual Message of Dec. 1845 say he comes strong on England France—and Mexico, to much so for the latter to have much to say on the question in hand, that its better to pay up give Texas and California too, turn over a new leaf—and begin again that the assistance Mexico may receive from Victoria will be rendered when she pays her Majesty's subjects some score of millions and thats never.

This country to show the world she goes ahead of Origen in other things besides producing five fold to the acre more grain, and cotten by & by to suit customers—is now discovering mines of every description—near the town of the Angels—there is a large sandy plain at the foot of some mountains where a common laborer can pick up placer gold to the amount of ten dollars & upwards a day—onze pcs have been found—the whole process to shake up the sand with water in a plate or flat basket—this gold is worth as it comes from the sand 12$ to 15$ in C—17$ in the U.S. per ozn. then there is said to be gold and silver mines—coal and slate mines—Bituminous Pitch—and salt are taken from many Ranchos by the cart loads. Some part of the coast the sea is oily coloured by this pich running from the banks, there is lead with the appearance of having melted and run among the shells and pebbles of the beach in the bay at San F.—the owner of the Rancho has not seen fit to trace it—nor look for the mine—there is near Monterey a metal obtained by pounding the ore and melting it in a pot, it has the appearance of pewter—80 miles north of Mont. on in Sonoma on the bay of San Fran^{c} there have quicksilver mines been opened—one of them is now occupied by a native of Mass—another by a person from Mass—the only method used is to break the ore on the surface by a crow bar and pick axe—and heat it in an oven. The vapor derived passes thro' some clay pipes into water—condensing into the present quicksilver yielding 75 to 25 pr ct. . . .

---

* From *Documents for the history of California: Papers of Thomas O. Larkin, Consul of the United States in California before the conquest, Tom. IV, part 2, 1846, doc. 183, presented by Sampson Tams to the Bancroft Library, 1875*. Published from the manuscript by courtesy of the Bancroft Library, University of California, Berkeley.

DISCOVERY OF GOLD AT SUTTER'S MILL AND EARLY DAYS OF THE GOLD RUSH

January 24, 1848 to August 23, 1848

JAMES W. MARSHALL

To J. M. Hutchings, on the Discovery of Gold January 24, 1848 *

Being a millwright by trade, as there was a ready cash sale for lumber, I concluded to seek a location in the mountains and erect a mill, to supply the valley with lumber. Some time in April, 1847, I visited New Helvetia, commonly known as the "Fort", where I made my resolution known to John A. Sutter, sen., and requested of him an Indian boy, to act as an interpreter to the mountain Indians in the vicinity of the American river—or Rio del los Americanos, as it was then called. At first he refused, because, he said that he had previously sent several companies, at various times, and by different routes, for that purpose, all of whom reported that it was impossible to find a route for a wagon road to any locality where pine timber could be procured, and that it was the height of folly to attempt any such thing.

Capt. Sutter at length, however, promised me the desired interpreter, provided I would stock some six or eight plows for him first, of which he was in immediate want, which I readily agreed to do. While I was employed upon this job there was much talk at the Fort concerning my contemplated trip to the mountains; and Messrs. Gingery, P. L. Wimmer and McLellan having resolved also to take a trip, with the same object in view, came where I was working, and asked me where I expected to find a road and timber, and I promptly gave them my views and directions.

They departed, I believe in company, but finally separated, and P. L. Wimmer found pine timber and a road, on what is now known as the Sacramento and Diamond Springs road, and about the 12th day of May, Gingery and Wimmer commenced work, about thirteen miles west of the (now called) Shingle Spring House.

On the 16th of May, having completed my work for Capt. Sutter, I started, with an Indian boy—Treador, and W. A. Graves (who is now residing in Butte County, and who had assisted me in my work, and heard the conversation between myself, Gingery, Wimmer, and McLellan,) accompanied me for the purpose of seeing the mountains. On the 18th of May we entered the valley of Culluma; and on the 20th Gingery joined our company. We then traveled up the stream now called Weber Creek—the Indian name for which is Pul-Pul-Mull—to the head of the creek; thence higher in the mountains until we arrived at the South Fork of the American river, where it divides into two branches of about equal size; from whence we returned by Sly Park and Pleasant Valley to the Fort.

On my arrival I gave Capt. Sutter an account of my trip, and what I had discovered. He thereupon proposed to me a partnership; but before we were ready to commence operations, some persons who had tried, in vain, to find Culluma, reported to Sutter that I "had made a false representation, for they could find no such place." To settle matters, Capt. Sutter furnished me with a Mission Indian, who was Alcalde of the Cosumnes tribe, as an interpreter and guide—trusting partly to the Indian's report, as to the propriety of the proposed co-partnership.

The report which I had made on my first trip having been fully confirmed by observations on the second, the co-partnership was completed, and about the 27th of August we signed the agreement to build and run a saw-mill at Culluma. On the third day (I think) afterwards, I set out, with two wagons,

---

* Published in *Hutchings' California Magazine*, vol. 2, no. 5, pp. 199-201, November 1857.

and was accompanied by the following persons, employed by the firm of Sutter & Marshall, viz.: P. L. Wimmer and family, James Barger, Ira Willis, Sidney Willis, Alexander Stephens, Wm. Cunce, James Brown, and Ezekiah Persons.

On our arrival in the Valley we first built the double log cabin, afterwards known as Hastings & Co.'s store. About the last of September, as Capt. Sutter wanted a couple of capable men to construct a dam across the American river at the grist-mill—near where the Pavilion now stands—I sent the two Willis', as the most capable; (Wm. Cunce being in feeble health, left about the same time;) and I received Henry Bigler, Israel Smith, Wm. Johnston and — Evans in return; and shortly afterwards I employed Charles Bennet and Wm. Scott, both carpenters. The above named individuals, with some ten Indians, constituted my whole force.

While we were in the habit at night of turning the water through the tail race we had dug for the purpose of widening and deepening the race, I used to go down in the morning to see what had been done by the water through the night; and about half past seven o'clock on or about the 19th of January —I am not quite certain to a day, but it was between the 18th and the 20th of that month—1848, I went down as usual, and after shutting off the water from the race I stepped into it, near the lower end, and there, upon the rock, about six inches beneath the surface of the water, I discovered the gold. I was entirely alone at the time. I picked up one or two pieces and examined them attentively; and having some general knowledge of minerals, I could not call to mind more than two which in any way resembled this—*sulphuret of iron,* very bright and brittle; and *gold,* bright, yet malleable; I then tried it between two rocks, and found that it could be beaten into a different shape, but not broken. I then collected four or five pieces and went up to Mr. Scott (who was working at the carpenter's bench making the mill wheel) with the pieces and said, "I have found it."

"What is it?" inquired Scott.

"Gold," I answered.

"Oh! no," returned Scott, "that can't be."

I replied positively—"I know it to be nothing else."

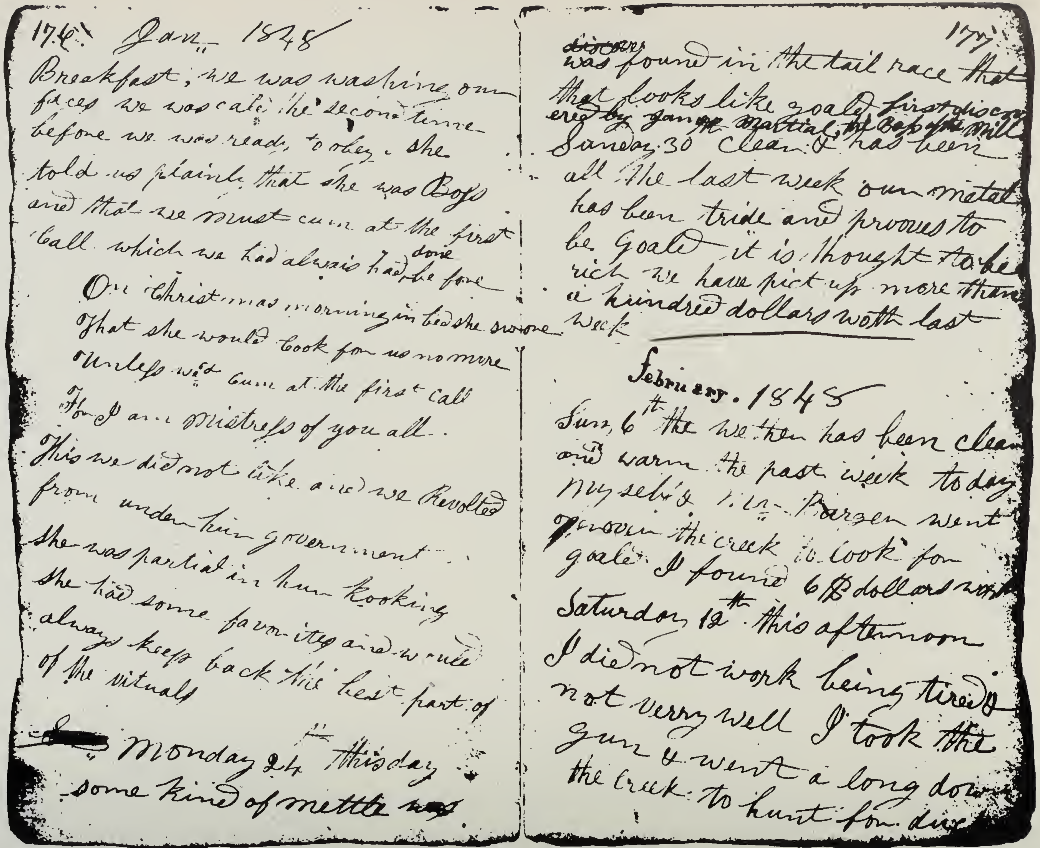
Mr. Scott was the second person who saw the gold. W. J. Johnston, A. Stephens, H. Bigler, and J. Brown, who were also working in the mill yard, were then called up to see it. Peter L. Wimmer, Mrs. Jane Wimmer, C. Bennet, and I. Smith, were at the house; the latter two of whom were sick; E. Persons and John Wimmer, (a son of P. L. Wimmer), were out hunting oxen at the same time. About 10 o'clock the same morning, P. L. Wimmer came down from the house, and was very much surprised at the discovery, when the metal was shown him; and which he took home to show his wife, who, the next day, made some experiments upon it by boiling it in strong lye, and saleratus; and Mr. Bennet by my directions beat it very thin.

Four days afterwards I went to the Fort for provisions, and carried with me about three ounces of the gold, which Capt. Sutter and I tested with *nitric acid.* I then tried it in Sutter's presence by taking three silver dollars and balancing them by the dust in the air, then immersed both in water, and the superior weight of the gold satisfied us both of its nature and value.

About the 20th of February, 1848, Capt. Sutter came to Coloma, for the first time, to consummate an agreement we had made with this tribe of Indians in the month of September previous, to wit:—that we live with them in peace, on the same land.

About the middle of April the mill commenced operation, and, after cutting a few thousand feet of lumber was abandoned; as all hands were intent upon gold digging. In December, '48, Capt. Sutter came again to Coloma, and some time in that month sold his interest in the mill to Messrs. Ragley & Winters, of which new firm I became a member. The mill was soon again in operation, and cut most of the lumber of which the town Coloma was built.

The first piece of gold, which I found, weighed about fifty cents. Mr. Wimmer, having bought a stock of merchandise some time about May or June, 1948; and Mrs. Wimmer being my treasurer, used four hundred and forty dollars of my money to complete the purchase; and among which was the first piece of gold which I had found. Where that went, or where it is now, I believe that nobody knows.



176 Jan 1848

Breakfast, we was washing our
faces we was call the second time
before we was ready to obey. she
told us plainly that she was Boss
and that we must cum at the first
call which we had always had done be fore

On Christmas morning in bed she swore
That she would Cook for us no more
Unless we'd cum at the first call
For I am mistress of you all.
This we did not like and we Revolted
from under her government.
She was partial in her Kooking
She had some favorites and would
always keep back the best part of
of the vituals

~~I~~ Monday 24th this day
some kind of mettle ~~was~~

177

~~discov~~
was found in the tail race that
that looks like goald ~~first discov~~
~~ered by James Martial, the Boss of the mill~~
Sunday 30 Clear & has been
all the last week our metal
has been tride and prooves to
be Goald it is thought to be
rich we have pickt up more than
a hundred dollars woth last
week

February. 1845

Sun, 6th the weather has been clear
and warm the past week today
myself & Wm. Barger went
down the creek to look for
goald I found 6$ dollars worth
Saturday 12th this afternoon
I did not work being tired &
not verry well I took the
gun & went a long down
the creek to hunt for du

FIGURE 1. Pages from the Henry W. Bigler diary recording the discovery of gold at Sutter's mill, January 24, 1848. Photo by courtesy of Society of California Pioneers, San Francisco.

THE DISCOVERY OF GOLD

As Recorded in the Diary of Henry W. Bigler, January 24, 1848 *

Monday 24th this day some kind of mettle was found in the tail race that looks like goald first discovered by James Martial, the Boss of the Mill.

Sunday 30th Clear and has been all the last week our metal has been tride and prooves to be goald it is thought to be rich we have pict up more than a hundred dollars woth last week

---

* Henry W. Bigler was one of the members of the Mormon Battalion who helped build Sutter's mill.

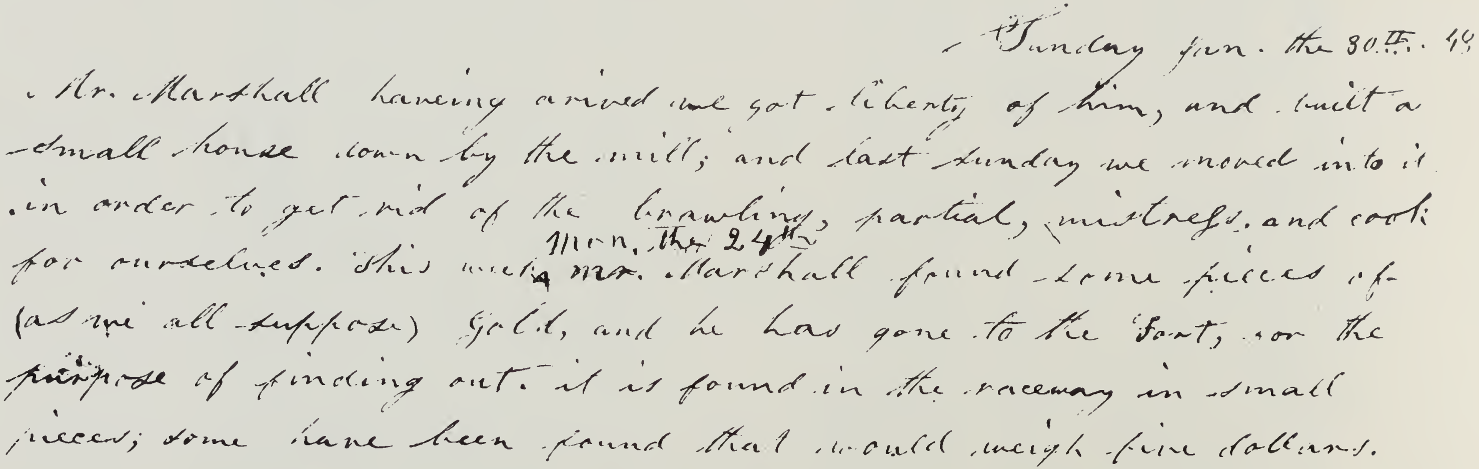
"The Mormon Battalion which was the force that followed Gen. Kearney from New Mexico under the command of Colonel Cook, were discharged or disbanded in 1847 and many of the Mormons came up to Sacramento and remained working for Sutter till after the discovery of gold in 1848.

"Some of them who had been sent by Sutter to help Marshal build the saw-mill were among the first to dig for gold after Marshal made the discovery. Some claimed (as Brigham Young told me in 1864) to have picked up gold before Marshal did but that was doubtless a mistake. Having supplied themselves with many useful things for the settlement at Salt Lake most of these Mormons left to join their families and friends who were to meet them at that place." John Bidwell, in *California, 1841-8;* reprinted from the manuscript by courtesy of Bancroft Library, University of California, Berkeley, California.

THE DISCOVERY OF GOLD

As Recorded in the Diary of Azariah Smith, January 30, 1848 *

Sunday Jan. the 16th Haveing rained three days last week it raised the river very high, and we expected to see the water go around the butment almost every minute; but thursday the Sun came out and it has been clear ever since. the days are tolerable warm but the nights are very cold. Mr. Marshall has now been gone to the fort a month, and has not come back yet, (with his mill irons) and mr. bennett has got very much out of patience waiting for him, but we expect him all the time. Today I went down to the river and washed. Sunday Jan. the 30th, 48 Mr. Marshall haveing arived we got liberty of him, and built a small house down by the mill; and last Sunday we moved into it in order to get rid of the brawling, partial, mistress, and cook for ourselves. This week mr. Marshall found some pieces of (as we all suppose) Gold, and he has gone to the Fort, for the purpose of finding out. it is found in the raceway in small pieces; some have been found that would weigh five dollars.



Sunday Jan. the 30th. 48

Mr. Marshall haveing arived we got liberty of him, and built a
small house down by the mill; and last Sunday we moved into it
in order to get rid of the brawling, partial, mistress, and cook
for ourselves. This week Mon. the 24th Mr. Marshall found some pieces of
(as we all suppose) Gold, and he has gone to the Fort, for the
purpose of finding out. it is found in the raceway in small
pieces; some have been found that would weigh five dollars.

FIGURE 2. Portion of a page from the Azariah Smith diary recording the discovery of gold at Sutter's mill. Reproduced by courtesy of Mrs. Hazel Bigler, Salt Lake City.

Sunday Febuary the 6th Mr. Marshall has returned with the fact that it is Gold; and captain Sutter came here wednesday with Johnston, for the purpose of looking at the mine, where the gold is found; and got enough for a ring. . . .

Monday Feb. the 14th The past week I did not work but three days and a half. Mr. Marshall grants us the privelege of picking up Gold odd spells and Sundays, and I have gathered up considerable. When we shut down the gates the gold is found in the bottom of the tale race. Sunday Feb. the 20th The fore part of the past week it rained and I did not work but four days, and I have been drilling a rock which is in the race, and blasting, which pleases the Indians very much to see the rock which is very hard, split open so easy. Today I picked up a little more of the root of all evil. Sunday March the 12th The two past weeks, as usial, I have been to work on the mill; and last sunday I picked up two dollars and a half, below this place about two miles. Today we started the mill, and sawed up one log and are pining it on the forebay. The mill runs very well; but the back water hinders some, and the tale race will have to be dug some deeper.

Sunday March the 19th Last week we ran the mill some and it cuts well, makeing beautifull plank. Today I crossed the river and went down it to hunt for Gold, and found some. . . .

. . . Tuesday March the 28th Last Sunday I with three others went down the river on the other side and picked up considerable Gold. . . .

Monday Appr. 3d Yesterday I with some others, again went down the river and picked up some more Gold. Friday April the 7th I have worked four days this week; but today I am laying by. Brothers Brown, Stephens, and Bigler started today for the Fort, but I thought that I would stay and work. Mr. Marshall has gave us the privelege of hunting Gold and haveing half we find, and we are a going to improve the opportunity. I have something like thirty dollars of it now.

Friday May the 26th I scraped one day on the race; when on the nineth the boys came back from the exploring expedition haveing went up to the back bone, which was covered with snow and they could not cross. They then concluded to go up to the Gold mine; so on thursday the 11th we went up, and stayed there untill Tuesday the 23d, when we came down. While there we had very good luck; I got there something near three hundred dollars. . . . the most I made in a day, was sixty five dollars after the toll was taken out, which was thirty dollars out of a hundred, which goes to hudson and Willis, that discovered the mine, and Brannon who is securing it for them. Before we came away, men, women and children, from the Bay, and other places in California; were flocking to the Gold mine, by the dozens, and by wagon loads. While there Brannon called a meeting, to see who was willing to pay toll and who was not. the most of them agreed to pay toll, but some of them would not. Agreeable to the council of brothers Rogers, Browett, and Holmes, I with Douglass, Dobson, Bennett, Moss and Rogers came down to finish the race, and fit ourselves out for going to Salt Lake vally by the middle of June. Some of the boys came here last night that have been getting Gold on the other side of the River.

---

* Azariah Smith was one of the members of the Mormon Battalion who helped to build Sutter's mill. The original diary is now in the possession of Mrs. Hazel Bigler of Salt Lake City, by whose permission this quotation is printed.

JOHN A. SUTTER

To J. M. Hutchings, on the Discovery of Gold, January 24, 1848 *

It was in the first part of January, 1848, when the gold was discovered at Coloma, where I was then building a saw-mill. The contractor and builder of this mill was James W. Marshall, from New Jersey. In the fall of 1847, after the mill seat had been located, I sent up to this place Mr. P. L. Wimmer with his family, and a number of laborers, from the disbanded Mormon Battalion; and a little later I engaged Mr. Bennet from Oregon to assist Mr. Marshall in the mechanical labors of the mill. Mr. Wimmer had the team in charge, assisted by his young sons, to do the necessary teaming, and Mrs. Wimmer did the cooking for all hands.

I was very much in need of a saw-mill, to get lumber to finish my large flouring mill, of four run of stones, at Brighton, which was commenced at the same time, and was rapidly progressing; likewise for other buildings, fences, etc., for the small village of Yerba Buena (now San Francisco). In the City Hotel, (the only one), at the dinner table this enterprise was unkindly called "another folly of Sutter's," as my first settlement at the old fort near Sacramento City was called by a good many, "a folly of his," and they were about right in that, because I had the best chances to get some of the finest locations, near the settlements; and even well-stocked rancho's had been offered to me on the most reasonable conditions; but I refused all these good offers, and preferred to explore the wilderness, and select a territory on the banks of the Sacramento. It was a rainy afternoon when Mr. Marshall arrived at my office in the Fort, very wet. I was somewhat surprised to see him, as he was down a few days previous; and when, I sent up to Coloma a number of teams with provisions, mill irons, etc., etc. He told me then that he had some important and interesting news which he wished to communicate secretly to me, and wished me to go with him to my private rooms; he requested me to lock the door; I complied, but I told him at the same time that nobody was in the house except the clerk, who was in his office in a different part of the house; after requesting of me something which he wanted, which my servants brought and then left the room, I forgot to lock the doors, and it happened that the door was opened by the clerk just at the moment when Marshall took a rag from his pocket, showing me the yellow metal: he had about two ounces of it; but how quick Mr. M. put the yellow metal in his pocket again can hardly be described. The clerk came to see me on business, and excused himself for interrupting me, and as soon as he had left I was told, "Now lock the doors; didn't I tell you that we might have listeners?" I told him that he need fear nothing about that, as it was not the habit of this gentleman; but I could hardly convince him that he need not to be suspicious. Then Mr. M. began to show me this metal, which consisted of small pieces and specimens, some of them worth a few dollars; he told me that he had expressed his opinion to the laborers at the mill, that this might be gold; but that some of them were laughing at him and called him a crazy man, and could not believe such a thing. After having proved the metal with aqua fortis, which I found in my apothecary shop, likewise with other experiments, and read the long article "gold" in the Encyclopedia Americana, I declared this to be gold of the finest quality, of at least 23 carats. After this

---

* Published in *Hutchings' California Magazine*, volume 2, number 5, pages 194-198, November 1857.

Mr. M. had no more rest nor patience, and wanted me to start with him immediately for Coloma; but I told him I could not leave, as it was late in the evening and nearly supper time, and that it would be better for him to remain with me till the next morning, and I would travel with him, but this would not do: he asked me only, "Will you come to-morrow morning?" I told him yes, and off he started for Coloma in the heaviest rain, although already very wet, taking nothing to eat. I took this news very easy, like all other occurrences good or bad, but thought a great deal during the night about the consequences which might follow such a discovery. I gave all my necessary orders to my numerous laborers, and left the next morning at 7 o'clock, accompanied by an Indian soldier, and vaquero, in a heavy rain, for Coloma. About half way on the road I saw at a distance a human being crawling out from the brushwood. I asked the Indian who it was; he told me, "The same man who was with you last evening." When I came nearer I found it was Marshall, very wet; I told him that he would have done better to remain with me at the fort than to pass such an ugly night here; but he told me that he went up to Coloma (54 miles), took his other horse and came half way to meet me; then we rode up to the new Eldorado. In the afternoon the weather was clearing up, and we made a prospecting promenade. The next morning we went to the tail-race of the mill, through which the water was running during the night, to clean out the gravel which had been made loose, for the purpose of widening the race; and after the water was out of the race we went in to search for gold. This was done every morning: small pieces of gold could be seen remaining on the bottom of the clean washed bed rock. I went in the race and picked up several pieces of this gold, several of the laborers gave me some which they had picked up, and from Marshall I received a part. I told them that I would get a ring made of this gold as soon as it could be done in California; and I have had a heavy ring made, with my family's coat of arms engraved on the outside, and on the inside of the ring is engraved, "The first gold, discovered in January, 1848." Now if Mrs. Wimmer possesses a piece which has been found earlier than mine Mr. Marshall can tell, as it was probably received from him. I think Mr. Marshall could have hardly known himself which was exactly the first little piece, among the whole.

The next day I went with Mr. M. on a prospecting tour in the vicinity of Coloma, and the following morning I left for Sacramento. Before my departure I had a conversation with all hands: I told them that I would consider it as a great favor if they would keep this discovery secret only for six weeks, so that I could finish my large flour mill at Brighton, (with four run of stones,) which had cost me already about from 24 to 25,000 dollars—the people up there promised to keep it secret so long. On my way home, instead of feeling happy and contented, I was very unhappy, and could not see that it would benefit me much, and I was perfectly right in thinking so; as it came just precisely as I expected. I thought at the same time that it could hardly be kept secret for six weeks; and in this I was not mistaken, for about two weeks later, after my return, I sent up several teams in charge of a white man, as the teamsters were Indian boys. This man was acquainted with all hands up there, and Mrs. Wimmer told him the whole secret; likewise the young sons of Mr. Wimmer told him that they had gold, and that they would let him have some too; and so he obtained a few dollars' worth of it as a present. As soon as this man arrived at the fort he went to a small store in one of my outside buildings, kept by Mr. Smith, a partner of Samuel Brannan, and asked for a bottle of brandy, for which he would pay the cash; after having the bottle he paid with these small pieces of gold. Smith was astonished and asked him if he intended to insult him; the teamster told him to go and ask me about it; Smith came in, in great haste, to see me, and I told him at once the truth—what could I do? I had to tell him all about it. He reported it to Mr. S. Brannan, who came up immediately to get all possible information, when he returned and sent up large supplies of goods, leased a larger house from me, and commenced a very large and profitable business; soon he opened a branch house of business at Mormon Island.

Mr. Brannan made a kind of claim on Mormon Island, and put a tolerably heavy tax on "The Latter Day Saints." I believe it was thirty per cent, which they paid for some time, until they got tired of it, (some of them told me that it was for the purpose of building a temple for the honor and glory of the Lord.)

So soon as the secret was out my laborers began to leave me, in small parties first, but then all left, from the clerk to the cook, and I was in great distress; only a few mechanics remained to finish some very necessary work which they had commenced, and about eight invalids, who continued slowly to work a few teams, to scrape out the mill race at Brighton. The Mormons did not like to leave my mill unfinished, but they got the gold fever like everybody else. After they had made their piles they left for the Great Salt Lake. So long as these people have been employed by me they have behaved very well, and were industrious and faithful laborers, and when settling their accounts there was not one of them who was not contented and satisfied.

Then the people commenced rushing up from San Francisco and other parts of California, in May, 1848: in the former village only five men were left to take care of the women and children. The single men locked their doors and left for "Sutter's Fort", and from there to the Eldorado. For some time the people in Monterey and farther south would not believe the news of the gold discovery, and said that it was only a '*Ruse de Guerre*' of Sutter's, because he wanted to have neighbors in his wilderness. From this time on I got only too many neighbors, and some very bad ones among them.

What a great misfortune was this sudden gold discovery for me! It has just broken up and ruined my hard, restless, and industrious labors, connected with many dangers of life, as I had many narrow escapes before I became properly established. From my mill buildings I reaped no benefit whatever, the mill stones even have been stolen and sold.

My tannery, which was then in a flourishing condition, and was carried on very profitably, was deserted, a large quantity of leather was left unfinished in the vats; and a great quantity of raw hides became valueless as they could not be sold; nobody wanted to be bothered with such trash, as it was called. So it was in all the other mechanical trades which I had carried on; all was abandoned, and work commenced or nearly finished was all left, to an immense loss for me. Even the Indians had no more patience to work alone, in harvesting and threshing my large wheat crop out; as the whites had all left, and other Indians had been engaged by some white men to work for them, and they commenced to have some gold for which they were buying all kinds of articles at enormous prices in the stores; which, when my Indians saw this, they wished very much to go to the mountains and dig gold. At last I consented, got a number of wagons ready, loaded them with provisions and goods of all kinds, employed a clerk, and left with about one hundred Indians, and about fifty Sandwich Islanders (Kanakas) which had joined those which I brought with me from the Islands. The first camp was about ten miles above Mormon Island, on the south fork of the American river. In a few weeks we became crowded, and it would no more pay, as my people made too many acquaintances. I broke

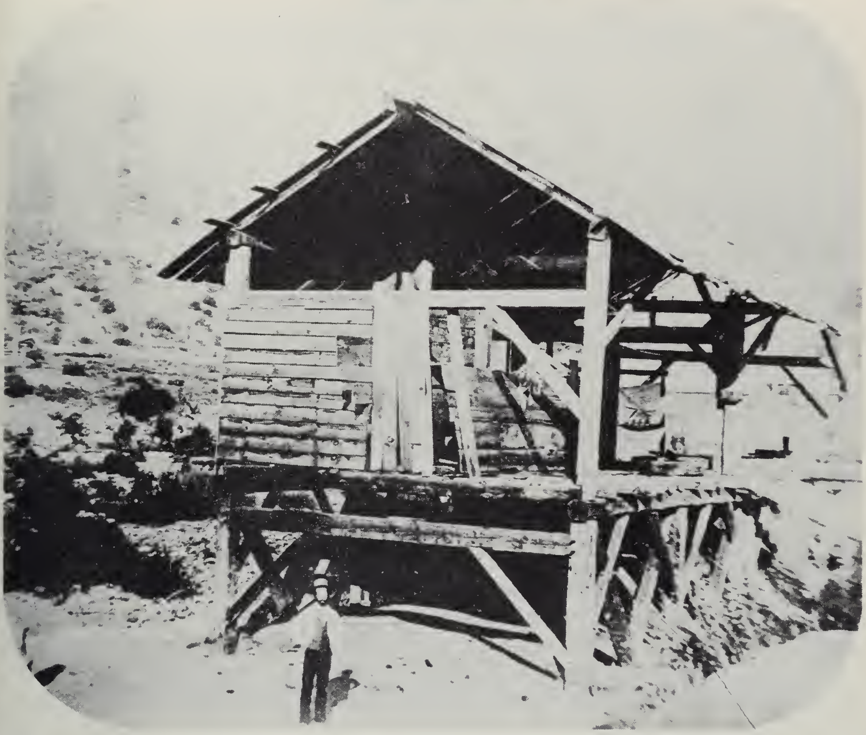


FIGURE 3. SUTTER'S MILL IN THE EARLY FIFTIES. Daguerreotype, depository unknown.

up the camp and started on the march further south, and located my next camp on Sutter creek (now in Amador county), and thought that I should there be alone. The work was going on well for a while, until three or four traveling grog-shops surrounded me, at from one and a half to two miles distance from the camp; then, of course, the gold was taken to these places, for drinking, gambling, etc., and then the following day they were sick and unable to work, and became deeper and more indebted to me, and particularly the Kanakas. I found that it was high time to quit this kind of business, and lose no more time and money. I therefore broke up the camp and returned to the Fort, where I disbanded nearly all the people who had worked for me in the mountains digging gold. This whole expedition proved to be a heavy loss to me.

At the same time I was engaged in a mercantile firm in Coloma, which I left in January, 1849—likewise with many sacrifices. After this I would have nothing more to do with the gold affairs. At this time, the Fort was the great trading place where nearly all the business was transacted. I had no pleasure to remain there, and moved up to Hock Farm, with all my Indians, and who had been with me from the time they were children. The place was then in charge of a Major Domo.

It is very singular that the Indians never found a piece of gold and brought it to me, as they very often did other specimens found in the ravines. I requested them continually to bring me some curiosities from the mountains, for which I always recompensed them. I have received animals, birds, plants, young trees, wild fruits, pipe clay, stones, red ochre, etc., etc., but never a piece of gold.

Mr. Dana, of the scientific corps of the expedition under Commodore Wilkes' Exploring Squadron, told me that he had the strongest proof and signs of gold in the vicinity of Shasta Mountain and further south. A short time afterwards, Doctor Sandels, a very scientific traveler, visited me, and explored a part of the country in a great hurry, as time would not permit him to make a longer stay. He told me likewise that he found sure signs of gold, and was very sorry that he could not explore the Sierra Nevada. He did not encourage me to attempt to work and open mines, as it was uncertain how it would pay, and would probably be only profitable for a government. So I thought it more prudent to stick to the plow, notwithstanding I did know that the country was rich in gold, and other minerals. An old attached Mexican servant who followed me here from the United States, as soon as he knew that I was here, and who understands a great deal about working in placers, told me he found sure signs of gold in the mountains on Bear Creek, and that we would go right to work after returning from our campaign in 1845, but he became a victim to his patriotism and fell into the hands of the enemy near my encampment, with dispatches for me from General Micheltorena, and he was hung as a spy, for which I was very sorry.

By this sudden discovery of the gold, all my great plans were destroyed. Had I succeeded with my mills and manufactories for a few years before the gold was discovered, I should have been the richest citizen on the Pacific shore; but it had to be different. Instead of being rich, I am ruined, and the cause of it is the long delay of the United States Land Commission, of the United States Courts, through the great influence of the squatter lawyers. Before my case will be decided in Washington, another year may elapse, but I hope that justice will be done me by the last tribunal—the Supreme Court of the United States. By the Land Commission and the District Court it has been decided in my favor. The Common Council of the city of Sacramento, composed partly of squatters, paid Alpheus Felch (one of the late Land Commissioners, who was engaged by the squatters during his office), $5,000, from the fund of the city, against the will of the tax-payers, for which amount he has to try to defeat my just and old claim from the Mexican Government, before the Supreme Court of the United States in Washington.

JOHN BIDWELL

On the Discovery of Gold, January 1848 *

In 1847 Sutter made another effort and succeeded in building a saw-mill. This time James W. Marshal was sent to explore for a site. He returned in time and reported that he had found a good site for a saw-mill on the American River about thirty-six miles distant. He said that by hauling the lumber about eighteen miles it could be rafted the rest of the way down the river to Sutter's Fort. A written agreement was entered into concerning the building of the mill between Sutter and Marshal—I wrote the agreement. Marshal was a natural mechanic, could build or make almost anything.

It took some time to make ready for such an enterprise. Marshal at length started with his tools on Mexican carts drawn by oxen. A band of sheep was sent along to furnish meat. The fall rains set in and delayed him on the way and it was two weeks before he reached the point for the saw-mill. The place is now known as Coloma, and instead of being thirty-six miles it was full fifty miles from Sutter's Fort, but to reach it at that time as he did with Mexican carts he traveled probably not less than eighty miles. Many if not most of the men sent to help Marshal had belonged to the Mormon Battalion. The mill was made, the dam constructed and the gate raised but the water wouldn't run up hill for the bar at the head of which the mill was built was higher that the water wheel. The remedy was to make a tail-race to conduct the water away from the wheel. Indians were set to work and the bowlders and gravel thrown out and still the race was not deep enough. A decayed granite bed-rock had to be sunk into to deepen the race. As soon as water would run through, the gate was opened at night and the water permitted to rush through and sweep away the sand. Before the men began to work in the morning, Marshal as his habit was, would go down to see where the race needed deepening most. On one of these occasions after the water had been running through the race during the night just fast enough to sweep away the lighter material, he saw a piece of gold. This was the first discovery. Soon other pieces were picked up by himself and some by others.

Marshal immediately started for Sutter's Fort. A man by the name of Bennett was sent to Monterey to see Gov. Riley with the view of denouncing the mine in favor of Sutter and Marshal according to the Mexican law which it was understood was still in force and would be till the United States should furnish for California a new code of laws. At the time of this discovery by Marshal I was near this place—Chico—surveying and building a house and making improvements.

Having occasion to go to San Rafael and San Francisco, I reached Sutter's Fort one or two days after Marshal had been there and announced his discovery. And I was the first to carry the news to San Francisco. I well remember Vallejo's words when I told him of the discovery and where it had taken place. He said "As the water flows through Sutter's mill-race may the gold flow into Sutter's purse." On my return I went up to the saw-mill to see the gold mine. A Mr. Humphrey a gold miner of Georgia and Ruelle had preceded us and were already washing gold with pans in some ravines on the north side of the river.

On my return to Chico I stopped over night at Hamilton on the west bank of Feather River. On trying some of the sand in the river here I found light particles of gold and reckoned that if light gold could be found that far down the river, the heavier particles would certainly remain near the hills. On reaching Chico an expedition was organized but it took some time to get everything ready. We had to send twice up to Peter Lassen's Mill to obtain flour, meat had to be dried, and we had to send to Sacramento for tools. In our party were Mr. Dicky, Potter, John Williams, Wm. Northgraves and myself. We passed near Cherokee and up on the North Fork. In nearly all the places we prospected we found the color. One evening while camped at White Rock Dicky and I in a short time panned out about an ounce of fine gold. The others refused to prospect any and said the gold we had obtained was so light that it would not weigh anything. At this time we were all unfamiliar with the weight of gold dust but I am satisfied that what we had would have weighed an ounce. At length we came home and some of the men went to the American River to mine. Dicky, Northgraves and I went to what is now Bidwell's Bar and there found gold and went to mining.

---

* From *California, 1841-8, An immigrant's recollections of a trip across the plains and of men and events in early days, including the Bear Flag revolution, by John Bidwell of Chico—written at the author's dictation by S. S. Boynton for the Bancroft Library, 1877.* Published from manuscript by courtesy of Bancroft Library, University of California, Berkeley, California.

THOMAS O. LARKIN

To James Buchanan, June 1, 1848 *

San Francisco, Upper California
June 1, 1848.

Sir: I have to report to the State Department one of the most astonishing excitements and state of affairs now existing in this country, that, perhaps, has ever been brought to the notice of the Government. On the American fork of the Sacramento and Feather River, another branch of the same, and the adjoining lands, there has been, within the present year, discovered a placer, a vast tract of land containing gold, in small particles. This gold, thus far, has been taken on the bank of the river, from the surface to eighteen inches in depth, and is supposed deeper, and to extend over the country. On account of the inconvenience of washing, the people have, to this time, only gathered the metal on the banks, which is done simply with a shovel, filling a shallow dish, bowl, basket, or tin pan with a quantity of black sand, similar to the class used on paper, and washing out the sand by movement of the vessel. It is now two or three weeks since the men employed in those washings have appeared in this town with gold, to exchange for merchandise and provisions. I presume nearly twenty thousand dollars ($20,000) of this gold has, as yet, been so exchanged. Some two or three hundred men have remained up the river, or are gone to their homes, for the purpose of returning to the placera, and washing immediately with shovels, picks, and baskets; many of them, for the first few weeks, depending on borrowing from others. I have seen the written statement of the work of one man for sixteen days, which average twenty-five dollars ($25) per day; others have, with a shovel and pan, or wooden bowl, washed out ten to even fifty dollars a day. There are now some men yet washing, who have five hundred to one thousand dollars. As they have to stand two feet deep in the river, they work but a few hours in the day, and not every day in the week. A few men have been down in boats to this port, spending twenty to thirty ounces of gold each—about three hundred dollars ($300). I am confident that this town (San Francisco) has one-half of its tenements empty, locked up with the furniture. The owners—storekeepers, lawyers, mechanics and laborers—all gone to the Sacramento with their families. Small parties, of five to fifteen men, have sent to this town, and offered cooks ten to fifteen dollars per day for a few weeks. Mechanics and teamsters, earning the year past five to eight dollars per day, have struck and gone. Several United States volunteers have deserted. United States bark Anita, belonging to the army, now at anchor here, has but six men. One Sandwich Island vessel in port lost all her men; engaged another crew at fifty dollars ($50) for the run of fifteen days to the islands. One American captain having his men shipped on this coast in such a manner that they could leave at any time, had them all on the eve of quitting, when he agreed to continue their pay and food; leaving one on board, he take a boat and carry them to the gold regions; furnishing tools and giving his men one-third. They have been gone a week. Common spades and shovels, one month ago worth one dollar, will now bring ten dollars at the gold regions. I am informed fifty dollars has been offered for one. Should this gold continue as represented, this town and others, would be depopulated. Clerks' wages have risen from six hundred to one thousand dollars per annum, and board; cooks', twenty-five to thirty dollars per month. This sum will not be any inducement a month longer, unless the fever and ague appears among the washers. The "Californian," printed here, stopped this week. The "Star" newspaper office, where the new laws of Governor Mason, for this country, is printing, has but one man left. A merchant, lately from China, has even lost his China servants. Should the excitement continue through the year, and the whale ships visit San Francisco, I think they will lose most all their crews. How Colonel Mason can retain his men, unless he puts a force on the spot, I know not. I have seen several pounds of this gold, and consider it very pure, worth, in New York, seventeen to eighteen dollars per ounce; fourteen to sixteen dollars, in merchandise, is paid for it here. What good or bad effect this gold region will have on California, I cannot foretell. It may end this year; but I am informed that it will continue many years. Mechanics now in this town are only waiting to finish some rude machinery, to enable them to obtain the gold more expeditiously, and free from working in the river. Up to this time, but few Californians have gone to the mines, being afraid the Americans will soon have trouble among themselves, and cause disturbance to all around. I have seen some of the black sand, as taken from the bottom of the river (I should think in the States it would bring twenty-five to fifty cents per pound), containing many pieces of gold; they are from the size of the head of a pin to the weight of the eighth of an ounce. I have seen some weighing one-quarter of an ounce (four dollars). Although my statements are almost incredible, I believe I am within the statements believed by every one here. Ten days back, the excitement had not reached Monterey. I shall, within a few days, visit this gold mine, and will make another report to you. Inclosed you will have a specimen.

---

* Printed in House Executive Document 1, pp. 51-52, for the 30th Congress, 2d Session, 1848-49.

I have the honor to be, very respectfully,

THOMAS O. LARKIN

HON. JAMES BUCHANAN, *Secretary of State, Washington*

P.S. This placer, or gold region, is situated on public land.

THOMAS O. LARKIN

To James Buchanan June 28, 1848 *

Mr. Larkin to Mr. Buchanan:

MONTEREY, CALIFORNIA
June 28, 1848.

SIR: My last despatch to the State Department was written in San Francisco, the 1st of this month. In that I had the honor to give some information respecting the new "placer," or gold regions lately discovered on the branches of the Sacramento river. Since the writing of that despatch, I have visited a part of the gold regions, and found it all I had heard, and much more than I anticipated. The part that I visited was upon a fork of the American River, a branch of the Sacramento, joining the main river at Sutter's Fort. The place in which I found the people digging was about twenty-five miles from the fort by land.

I have reason to believe that gold will be found on many branches of the Sacramento and the Joaquim rivers. People are already scattered over one hundred miles of land, and it is supposed that the "placer" extends from river to river. At present the workmen are employed within ten or twenty yards of the river, that they may be convenient to water. On Feather river, there are several branches upon which the people are digging for gold. This is two or three days' ride from the place I visited.

At my camping place I found, on a surface of two or three miles on the banks of the river, some fifty tents, mostly owned by Americans. These had their families. There are no Californians who have taken their families as yet to the gold regions; but few or none will ever do it. Some from New Mexico may do so next year, but no Californians.

I was two nights at a tent occupied by eight Americans, viz: two sailors, one clerk, two carpenters, and three daily workmen. These men were in company; had two machines, each made from one hundred feet of boards (worth there one hundred and fifty dollars; in Monterey, fifteen dollars—being one day's work), made similar to a child's cradle, ten feet long, without the ends.

The two evenings I saw these eight men bring to their tents the labor of the day. I suppose they made each fifty dollars per day; their own calculation was two pounds of gold a day—four ounces to a man—sixty-four dollars. I saw two brothers that worked together, and only worked by washing the dirt in a tin pan, weigh the gold they obtained in one day; the result was, seven dollars to one and eighty-two dollars to the other. There were two reasons for this difference; one man worked less hours than the other, and by chance had ground less impregnated with gold. I give this statement as an extreme case. During my visit I was an interpreter for a native of Monterey, who was purchasing a machine or canoe. I first tried to purchase boards and hire a carpenter for him. There were but a few hundred feet of boards to be had; for these the owner asked me fifty dollars per hundred ($500 per M), and a carpenter washing gold dust demanded fifty dollars per day for working. I at last purchased a log dug out, with a riddle and sieve made of willow-boughs on it, for one hundred and twenty dollars, payable in gold dust at fourteen dollars per ounce. The owner excused himself for the price, by saying that he was two days making it, and even then demanded the use of it until sunset. My

---

* Printed in House Executive Document 1, pp. 53-56, for the 30th Congress, 2d Session, 1848-49.

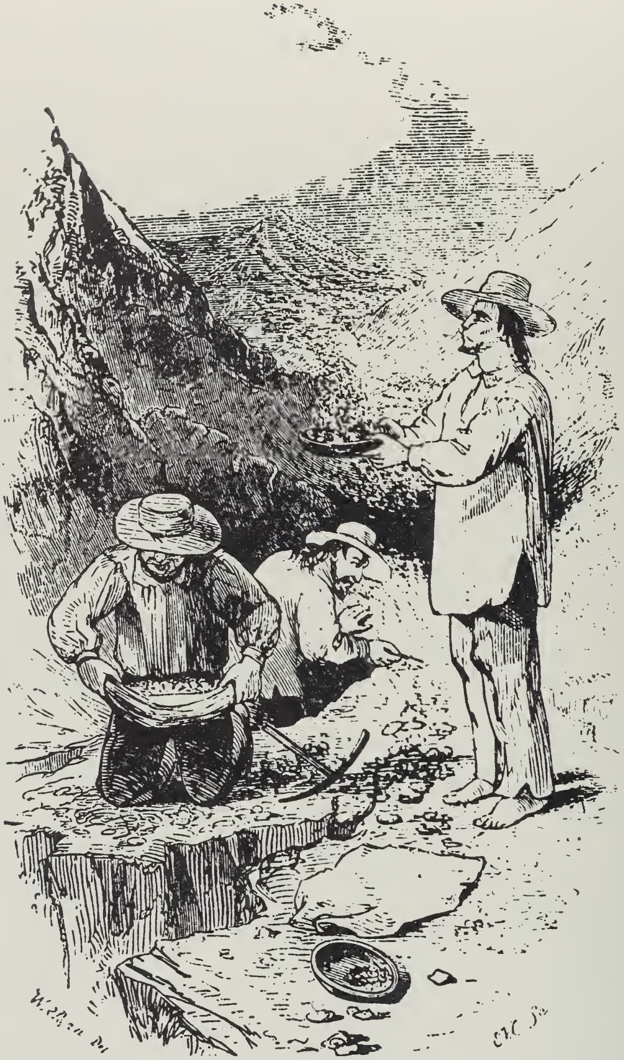


FIGURE 4. THE "DIGGINS"—SONOREANS DRY-WASHING GOLD: W. R. Ryan, Del.; E. V. C. (?), Sc. Photo by courtesy of California Historical Society, San Francisco.

Californian has told me since that himself, partner, and two Indians obtained with this canoe eight ounces the first and five ounces the second day.

I am of the opinion that, on the American Fork, Feather river, and Copimes river, there are near two thousand people, nine-tenths of them foreigners. Perhaps there are one hundred families, that have their teams, wagons and tents. Many persons are waiting to see whether the months of July and August will be sickly, before they leave their present business to go to the "placer." The discovery of this gold was made by some Mormons, in January or February, who for a time kept it a secret; the majority of those who are working there began in May. In most every instance the men, after digging a few days, have been compelled to leave for the purpose of returning home to see their families, arrange their business, and purchase provisions. I feel confident in saying there are fifty men in this "placer" who have on an average one thousand dollars each, obtained in May and June. I have not met with any person who had been fully employed in washing gold one month; most, however, appear to have averaged an ounce per day. I think there must at this time be over one thousand men at work upon the different branches of the Sacramento; putting their gains at ten thousand per day, for six days in the week, appears to me not overrated.

Should this news reach the emigration of California and Oregon, now on the road, connected with the Indian wars, now impoverishing the latter country, we should have a large addition to our population; and should the richness of the gold regions continue, our emigration in 1849 will be many thousand, and in 1850 still more. If our countrymen in California as clerks, mechanics, and workmen, will forsake employment at from two dollars to six dollars per day, how many more of the same class in the Atlantic States, earning much less, will leave for this country under such prospects? It is the opinion of many who have visited the gold regions the past and present months, that the ground will afford gold for many years, perhaps for a century. From my own examination of the rivers and their banks, I am of the opinion that, at least for a few years, the golden products will equal the present year. However, as neither men of science, nor the laborers now at work, have made any explorations of consequence, it is a matter of impossibility to give any opinion as to the extent and richness of this part of California. Every Mexican who has seen the place says throughout their republic there has never been any "placer" like this one.

Could Mr. Polk and yourself see California as we now see it, you would think that a few thousand people, on one hundred miles square of the Sacramento Valley, would yearly turn out of this river the whole price our country pays for all the acquired territory. When I finished my first letter I doubted my own writing, and, to be better satisfied, showed it to one of the principal merchants of San Francisco, and to Captain Fulsom, of the quartermaster's department, who decided at once I was far below the reality. You certainly will suppose, from my two letters, that I am, like others, led away by the excitement of the day. I think I am not.

In my last I enclosed a small sample of the gold dust, and I find my only error was in putting a value to the sand. At that time I was not aware how the gold was found; I can now describe the mode of collecting it. A person without a machine, after digging off one or two feet of the upper ground, near the water (in some cases they take the top earth), throws into a tin pan or wooden bowl a shovelful of loose dirt and stones; then, placing the basin an inch under water, continues to stir up the dirt with his hand in such a manner that the running water will carry off the light earth, occasionally, with his

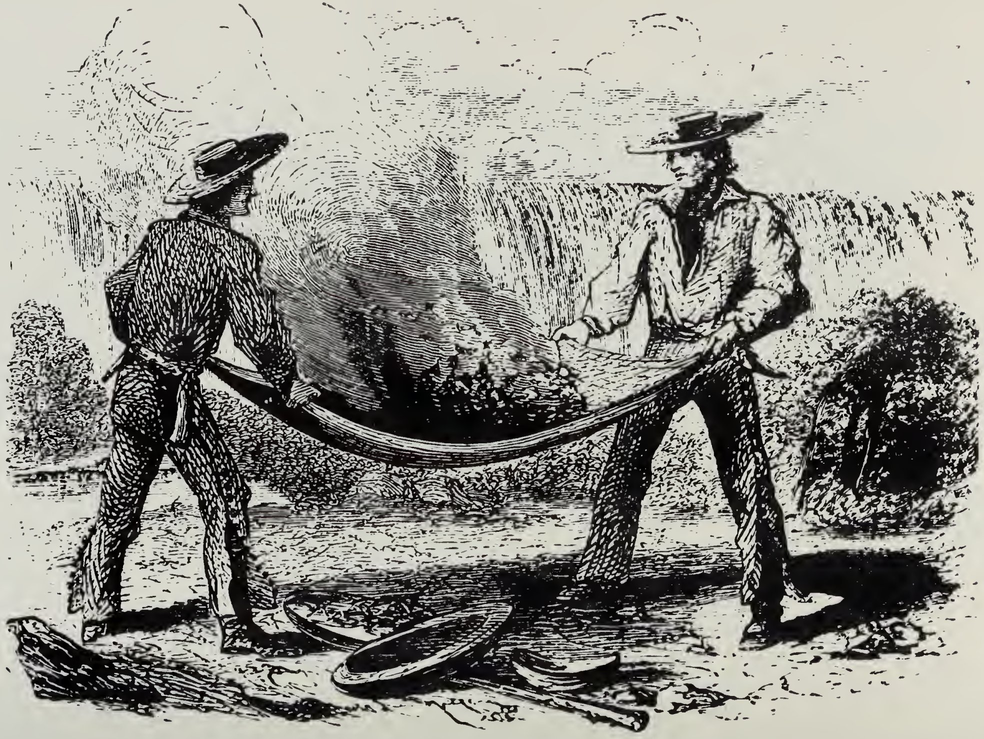


FIGURE 5. WINNOWING GOLD NEAR CHINESE CAMP. Photo after *California, A Book for Travellers and Settlers*, by Charles Nordhoff, 1873, by courtesy of California Historical Society, San Francisco.

hand, throwing out the stones; after an operation of this kind for twenty or thirty minutes, a spoonful of small black sand remains; this is on a handkerchief or cloth dried in the sun, the emerge is blown off, leaving the pure gold. I have the pleasure of enclosing a paper of this sand and gold, which I, from a bucket of dirt and stones, in half hour, standing at the edge of the water, washed out myself. The value of it may be two or three dollars.

The size of the gold depends in some measure upon the river from which it is taken, the banks of one river having larger grains of gold than another. I presume more than one-half of the gold put into pans or machines is washed out and goes down the stream; this is of no consequence to the washers, who care only for the present time. Some have formed companies of four or five men, and have a rough made machine put together in a day, which worked to much advantage, yet many prefer to work alone, with a wooden bowl or tin pan, worth fifteen or twenty cents in the States, but eight to sixteen dollars at the gold region. As the workmen continue and materials can be obtained, improvements will take place in the mode of obtaining gold; at present it is obtained by standing in the water, and with much severe labor, or such as is called here severe labor.

How long this gathering of gold by the handful will continue here, or the future effect it will have on California, I cannot say. Three-fourths of the houses in the town on the bay of San Francisco are deserted. Houses are sold at the price of the ground lots. The effects are this week showing themselves in Monterey. Almost every house I had hired out is given up. Every blacksmith, carpenter and lawyer is leaving; brick yards, saw mills, and ranches are left perfectly alone. A large number of the volunteers at San Francisco and Sonoma have deserted; some have been retaken and brought back; public and private vessels are losing their crews; my clerks have had one hundred per cent advance offered them on their wages to accept employment. A complete revolution in the ordinary state of affairs is taking place; both of our newspapers are discontinued from want of workmen and the loss of their agencies; the alcaldes have left San Francisco, and I believe Sonoma likewise; the former place has not a justice of the peace left.

The second alcalde of Monterey today joins the keepers of our principal hotel, who have closed their office and house, and will leave tomorrow for the golden rivers. I saw on the ground a lawyer who was last year attorney general of the king of the Sandwich Islands, digging and washing out his ounce and a half per day; near him can be found most all his brethren of the long robe, working in the same occupation.

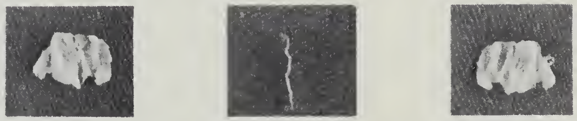
To conclude; my letter is long, but I could not well describe what I have seen in less words, and I now can believe that my account may be doubted; if the affair proves a bubble, a mere excitement; I know not how we can all be deceived, as we are situated. Governor Mason and his staff have left Monterey to visit the place in question, and will I suppose soon forward to his department his views and opinions on the subject. Most of the land, where gold has been discovered, is public land; there are on different rivers some private grants. I have three such purchased in 1846 and '47, but have not learned that any private lands have produced gold, though they may hereafter do so.

I have the honor, dear sir, to be, very respectfully,
Your obedient servant,

Thomas O. Larkin

Hon. James Buchanan, Secretary of State, Washington City.

CALIFORNIA STATE EXHIBIT



MARSHALL'S FIRST FLAKE OF GOLD

Photographs, exact size, showing both sides and edge view. It was hammered out by Marshall to test its malleability. Original is in Smithsonian Institution, Washington, D. C.

FIGURE 6.

JOSEPH L. FOLSOM

On Marshall's First Flake of Gold, August 23, 1848 *

Qur.Mr's. office
San Francisco N. C.
August 23d 1848.

This paper contains the first piece of gold ever discovered in the northern part of Upper California.

It was found in February 1848 † by James W. Marshall in the race of Capt. Jno. A. Sutter's saw mill, about forty five miles from Sutter's Fort, on the south branch of the American Fork. It was beaten out with a hammer by Mr. Marshall, to test its malleability.

It is presented to the National Institute Washington D.C.

J. L. Folsom
capt.asst.Qm.

---

* This letter, written by Joseph L. Folsom, Captain, U. S. Quartermaster's Dept., accompanied the first flake of gold found by James W. Marshall, to Washington, D. C.

† According to the Bigler diary, the piece of gold was picked up January 24, 1848 (see page 31).

COLONEL R. B. MASON

To General R. Jones August 17, 1848 *

Headquarters Tenth Military Department
Monterey, California, August 17, 1848.

Sir: I have the honor to inform you that, accompanied by Lieutenant W. T. Sherman, 3d artillery, acting assistant adjutant general, I started on the 12th of June last to make a tour through the northern part of California. My principal purpose, however, was to visit the newly-discovered gold placer in the valley of the Sacramento.

I had proceeded about forty miles when I was overtaken by an express, bringing me intelligence of the arrival at Monterey of the United States store ship Southampton, with important letters from Commodore Shubrick and Lieutenant Colonel Burton. I returned at once to Monterey, and despatched what business was most important, and on the 17th resumed my journey. We reached San Francisco on the 20th, and found that all, or nearly all, its male population had gone to the mines. The town, which a few months before was so busy and thriving, was then almost deserted. On the evening of the 24th, the horses of the escort were crossed to Sansolito in a launch, and on the following day we resumed the journey, by way of Bodega and Sonoma, to Sutter's Fort, where we arrived on the morning of the 2d of July. Along the whole route mills were lying idle, fields of wheat were open to cattle and horses, houses vacant, and farms going to waste. At Sutter's there was more life and business. Launches were discharging their cargoes at the river, and carts were hauling goods to the fort, where already were established several stores, a hotel, &c. Captain Sutter had only two mechanics in his employ—a wagon-maker and blacksmith—whom he was then paying ten dollars per day. Merchants pay him a monthly rent of one hundred dollars per room, and whilst I was there a two-story house in the fort was rented as a hotel for five hundred dollars a month.

At the urgent solicitation of many gentlemen, I delayed there to participate in the first public celebration of our national anniversary at that fort, but on the 5th resumed the journey and proceeded twenty-five miles up the American Fork, to a point on it now known as the lower mines, or Mormon diggings. The hill sides were thickly strewn with canvass tents and bush arbors. A store was erected, and several boarding shanties in operation. The day was intensely hot, yet about two hundred men were at work in the full glare of the sun, washing for gold, some with tin pans, some with close-woven Indian baskets, but the greater part had a rude machine known as the cradle. This is on rockers six or eight feet long, open at the foot, and at its head has a coarse grate and sieve; the bottom is rounded, with small cleets nailed across. Four men are required to work this machine; one digs the gravel in the bank close by the stream, another carries it to the cradle and empties it on the grate, a third gives a violent rocking motion to the machine, whilst a fourth dashes water on from the stream itself. The sieve keeps the coarse stones from entering the cradle, the current of water washes off the earthy matter, and the gravel is gradually carried out at the foot of the machine, leaving the gold mixed with a fine heavy black sand above the first cleets. The sand and gold, mixed together, are then drawn off through auger holes into a pan below, are dried in the sun, and afterwards separated by blowing off the sand. A party of four men thus employed at the lower mines averaged a hundred dollars a day. The Indians, and those who have nothing but pans or willow baskets, gradually wash out the earth and separate the gravel by hand, leaving nothing but the gold mixed with sand, which is separated in the manner before described. The gold in the lower mines is in fine bright scales, of which I sent several specimens.

---

* As printed in House Ex. Doc. 17, 31st Cong., 1st sess., pp. 529-536, 1850. Colonel Mason was commanding officer of the United States forces in California, and acting governor.

As we ascended the south branch of the American Fork, the country became more broken and mountainous, and at the saw-mill, twenty-five miles above the lower washings, or fifty miles from Sutter's, the hills rise to about a thousand feet above the level of the Sacramento plain. Here a species of pine occurs, which led to the discovery of the gold. Captain Sutter, feeling the great want of lumber, contracted, in September last, with a Mr. Marshall, to build a saw-mill at that place. It was erected in the course of the past winter and spring—a dam and race constructed; but when the water was let on the wheel, the tail race was found to be too narrow to permit the water to escape with sufficient rapidity. Mr. Marshall, to save labor, let the water directly into the race, with a strong current, so as to wash it wider and deeper. He effected his purpose, and a large bed of mud and gravel was carried to the foot of the race. One day Mr. Marshall, when walking down the race to this deposite of mud, observed some glittering particles at its upper edge: he gathered a few, examined them, and became satisfied of their value. He then went to the fort, told Captain Sutter of his discovery, and they agreed to keep it secret until a certain grist-mill of Sutter's was finished. It however got out, and spread like magic. Remarkable success attended the labors of the first explorers, and in a few weeks hundreds of men were drawn thither. At the time of my visit, but little more than three months after its first discovery, it was estimated that upwards of four thousand people were employed. At the mill there is a fine deposite, or bank of gravel, which the people respect as the property of Captain Sutter, although he pretends to no right to it, and would be perfectly satisfied with the simple promise of a pre-emption, on account of the mill which he has built there, at considerable cost. Mr. Marshall was living near the mill, and informed me that many persons were employed above and below him, and they used the same machines as at the lower washings, and that their success was about the same, ranging from one to three ounces of gold per man daily. This gold too is in scales, a little coarser than those of the lower mines. From the mills Mr. Marshall guided me up the mountain, on the opposite or north bank of the South Fork, where, in the beds of small streams, or ravines, now dry, a great deal of the coarse gold has been found. I there saw several parties at work, all of whom were doing very well. A great many specimens were shown me, some as heavy as four or five ounces in weight; and I send three pieces, labelled No. 5, presented by a Mr. Spence. You will perceive that some of the specimens accompanying this hold, mechanically, pieces of quartz, that the surface is rough, and evidently moulded in the crevice of a rock. This gold cannot have been carried far by water, but must have remained near where it was deposited from the rock that once bound it. I inquired of many people if they had encountered the metal in its matrix, but in every instance they said they had not, but that the gold was invariably mixed with washed gravel, or lodged in the crevices of other rocks. All bore testimony that they had found gold in greater or less quantities in the numerous small gullies or ravines that occur in that mountainous region. On the 7th of July I left the mill and crossed to a small stream emptying into the American Fork, three or four miles below the saw-mill. I struck this stream (now known as Weber's creek) at the washings of Suñal & Co. They had about thirty Indians employed, whom they pay in merchandise. They were getting gold of a character similar to that found in the main fork, and doubtless in sufficient quantities to satisfy them. I send you a small specimen, presented by this company, of their gold. From this point we proceeded up the stream about eight miles, where we found a great many people and Indians; some engaged in the bed of the stream, and others in the small side valleys that put into it. These latter were exceedingly rich, and two ounces were considered an ordinary yield for a day's work. A small gutter, not more than a hundred yards long by four feet wide and two or three feet deep, was pointed out to me as the one where two men, William Daly and Perry McCoon, had, a short time before, obtained in seven days $17,000 worth of gold.

Captain Weber informed me that he knew that these two men had employed four white men and about a hundred Indians, and that, at the end of one week's work, they paid off their party and had left with $10,000 worth of this gold. Another small ravine was shown me, from which had been taken $12,000 worth of gold. Hundreds of similar ravines, to all appearances, are as yet untouched. I could not have credited these reports had I not seen, in the abundance of the precious metal, evidence of their truth. Mr. Neligh, an agent of Commodore Stockton, had been at work about three weeks in the neighborhood, and showed me, in bags and bottles, over $2,000 worth of gold; and Mr. Lyman, a gentleman of education and worthy of every credit, said he had been engaged, with four others, with a machine, on the American Fork, just below Sutter's saw-mill, that they worked eight days, and that his share was at the rate of fifty dollars a day; but, hearing that others were doing better at Weber's place, they had removed there, and were then on the point of resuming operations.

I might tell of hundreds of similar instances; but to illustrate how plentiful the gold was in the pockets of common laborers, I will mention a simple occurrence which took place in my presence when I was at Weber's store. This store was nothing but an arbor of bushes, under which he had exposed for sale goods and groceries suited to his customers. A man came in, picked up a box of seidlitz powders, and asked its price. Captain Weber told him it was not for sale. The man offered an ounce of gold, but Captain Weber told him it only cost fifty cents, and he did not wish to sell it. The man then offered an ounce and a half, when Captain Weber *had* to take it. The prices of all things are high; and yet Indians, who before hardly knew what a breech-cloth was, can now afford to buy the most gaudy dresses.

The country, on either side of Weber's creek, is much broken up by hills, and is intersected in every direction by small streams or ravines, which contain more or less gold. Those that have been worked are barely scratched, and, although thousands of ounces have been carried away, I do not consider that a serious impression has been made upon the whole. Every day was developing new and rich deposites, and the only apprehension seemed to be that the metal would be found in such abundance as seriously to depreciate in value.

On the 8th of July I returned to the lower mines, and on the following day to Sutter's, where, on the 10th, I was making preparations for a visit to the Feather, Yubah, and Bear rivers, when I received a letter from Commodore A. R. Long, United States navy, who had just arrived at San Francisco from Mazatlan, with a crew for the sloop-of-war Warren, and with orders to take that vessel to the squadron at La Paz. Captain Long wrote to me that the Mexican Congress had adjourned without ratifying the treaty of peace, that he had letters for me from Commodore Jones, and that his orders were to sail with the Warren on or before the 20th of July. In consequence of these, I determined to return to Monterey, and accordingly arrived here on the 17th of July. Before leaving Sutter's, I satisfied myself that gold exists in the bed of the Feather river, in the Yubah, and Bear, and in many of the small streams that lie between the latter and the American Fork; also, that it had been found in the Cosumnes, to the south of the American Fork. In each of those streams the gold is found in small scales, whereas in the intervening mountains it occurs in coarse lumps.

Mr. Sinclair, whose rancho is three miles above Sutter's, on the north side of the American, employs about fifty Indians on the North Fork, not far from its junction with the main stream. He had been engaged about five weeks when I saw him, and up to that time his Indians had used simply closely-woven willow baskets. His nett proceeds (which I saw) were about $16,000 worth of gold. He showed me the proceeds of his last week's work—fourteen pounds avoirdupois of clean washed gold.

The principal store at Sutter's Fort, that of Brannant & Co., had received in payment for goods $36,000 worth of this gold from the 1st of May to the 10th of July; other merchants had also made extensive sales. Large quantities of goods were daily sent forward to the mines, as the Indians, heretofore so poor and degraded, have suddenly become consumers of the luxuries of life. I before mentioned that the greater part of the farmers and rancheros had abandoned their fields to go to the mines; this is not the case with Captain Sutter, who was carefully gathering his wheat, estimated at 40,000 bushels. Flour is already worth at Sutter's $36 a barrel, and soon will be fifty. Unless large quantities of breadstuffs reach the country, much suffering will occur; but as each man is now able to pay a large price, it is believed the merchants will bring from Chili and Oregon a plentiful supply for the coming winter.

The most moderate estimate I could obtain from men acquainted with the subject was, that upwards of four thousand men were working in the gold district, of whom more than half were Indians, and that from $30,000 to $50,000 worth of gold, if not more, was daily obtained. The entire gold district, with very few exceptions of grants made some years ago by the American authorities is on land belonging to the United States. It was a matter of serious reflection with me how I could secure to the government certain rents or fees for the privilege of procuring this gold; but upon considering the large extent of country, the character of the people engaged, and the small force at my command, I resolved not to interfere, but permit all to work freely, unless broils and crimes should call for interference. I was surprised to learn that crime of any kind was very unfrequent, and that no thefts or robberies had been committed in the gold district. All live in tents, in bush houses, or in the open air, and men have frequently about their persons thousands of dollars' worth of this gold; and it was to me a matter of surprise that so peaceful and quiet a state of things should continue to exist. Conflicting claims to particular spots of ground may cause collisions, but they will be rare, as the extent of the country is so great, and the gold so abundant, that for the present there is room and enough for all; still the government is entitled to rents for this land, and immediate steps should be devised to collect them, for the longer it is delayed the more difficult it will become. One plan I would suggest is to send out from the United States surveyors, with high salaries, bound to serve specified periods; a superintendent to be appointed at Sutter's Fort, with power to grant licenses to work a spot of ground, say 100 yards square, for one year,

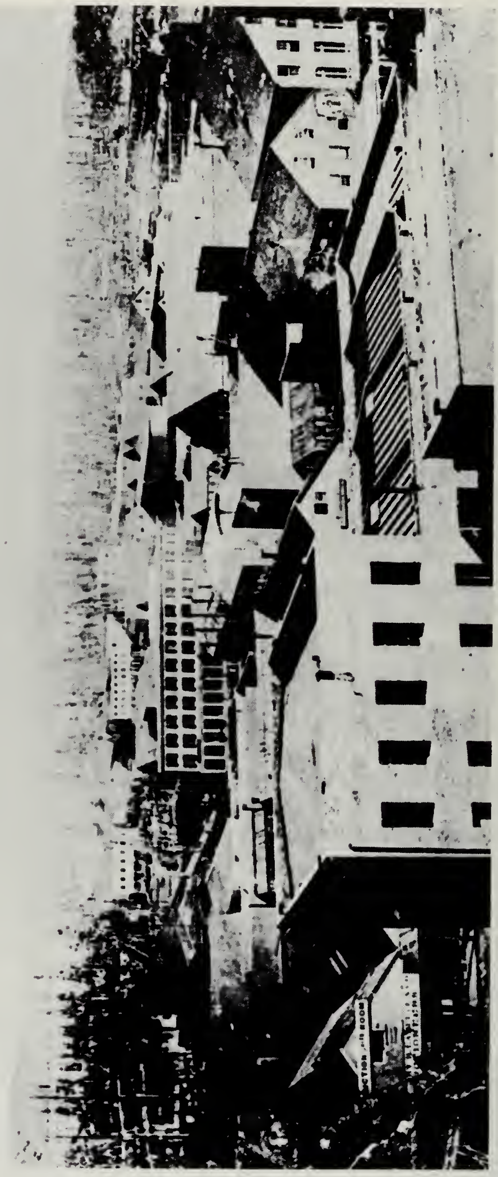


FIGURE 7. SAN FRANCISCO IN 1850. Masts of abandoned ships may be seen in the background. Daguerreotype, depository unknown. Photo by courtesy of California Historical Society, San Francisco.

at a rent of from $100 to $1,000, at his discretion; the surveyors to measure the grounds and place the renter in possession. A better plan, however, will be to have the district surveyed and sold at public auction to the highest bidder, in small parcels, say from 20 to 40 acres. In either case, there will be many intruders, whom for years it will be almost impossible to exclude.

The discovery of these vast deposites of gold has entirely changed the character of Upper California. Its people, before engaged in cultivating their small patches of ground and guarding their herds of cattle and horses, have all gone to the mines, or are on their way thither; laborers of every trade have left their work-brenches, and tradesmen their shops; sailors desert their ships as fast as they arrive on the coast, and several vessels have gone to sea with hardly enough hands to spread a sail; two or three are now at anchor in San Francisco with no crews on board. Many desertions, too, have taken place from the garrisons within the influence of the mines; 26 soldiers have deserted from the post of Sonoma, 24 from that of San Francisco, and 24 from Monterey. For a few days the evil appeared so threatening that great danger existed that the garrisons would leave in a body; and I refer you to my orders of the 25th of July to show the steps adopted to meet this contingency. I shall spare no exertions to apprehend and punish deserters; but I believe no time in the history of our country has presented such temptations to desert as now exist in California. The danger of apprehension is small, and the prospect of higher wages certain; pay and bounties are trifles, as laboring men at the mines can now earn in *one day* more than double a soldier's pay and allowances for a month, and even the pay of a lieutenant or captain cannot hire a servant. A carpenter or mechanic would not listen to an offer of less than fifteen or twenty dollars a day. Could any combination of affairs try a man's fidelity more than this? And I really think some extraordinary mark of favor should be given to those soldiers who remain faithful to their flag throughout this tempting crisis. No officer can now live in California on his pay. Money has so little value, the prices of necessary articles of clothing and subsistence are so exorbitant, and labor so high, that to hire a cook or servant has become an impossibility, save to those who are earning from thirty to fifty dollars a day. This state of things cannot last forever; yet, from the geographical position of California, and the new character it has assumed as a mining country, prices of labor will always be high, and will hold out temptations to desert. I therefore have to report, if the government wish to prevent desertions here on the part of men, and to secure zeal on the part of officers, their pay must be increased very materially. Soldiers both of the volunteer and regular service discharged in this country should be permitted at once to locate their land warrants in the gold district. Many private letters have gone to the United States giving accounts of the vast quantity of gold recently discovered, and it may be a matter of surprise why I have made no report on this subject at an earlier date. The reason is, that I could not bring myself to believe the reports that I heard of the wealth of the gold district until I visited it myself. I have no hesitation now in saying that there is more gold in the country drained by the Sacramento and San Joaquin rivers than will pay the cost of the present war with Mexico a hundred times over. No capital is required to obtain this gold, as the laboring man wants nothing but his pick, shovel, and tin pan, with which to dig and wash the gravel; and many frequently pick gold out of the crevices of rock with their butcher knives in pieces from one to six ounces.

Mr. Dye, a gentleman residing in Monterey, and worthy of every credit, has just returned from Feather river. He tells me that the company to which he belonged worked seven weeks and two days, with an average of fifty Indians, (washers,) and that their gross product was 273 pounds of gold. His share, one-seventh, after paying all expenses, is about 37 pounds, which he brought with him and exhibits in Monterey. I see no laboring man from the mines who does not show his two, three, or four pounds of gold. A soldier of the artillery company returned here a few days ago from the mines, having been absent on furlough twenty days; he made by trading and working during that time $1,500. During these twenty days he was travelling ten or eleven days, leaving but a week, in which he made a sum of money greater than he receives in pay, clothes, and rations during a whole enlistment of five years. These statements appear incredible, but they are true.

Gold is believed also to exist on the eastern slopes of the Sierra Nevada; and when at the mines, I was informed by an intelligent Mormon that it had been found near the Great Salt lake by some of his fraternity. Nearly all the Mormons are leaving California to go to the Salt lake, and this they surely would not do unless they were sure of finding gold there in the same abundance as they now do on the Sacramento.

The gold "placer" near the mission of San Fernando has long been known, but has been but little wrought for want of water. This is a spur that puts off from the Sierra Nevada, (see Fremont's map,) the same in which the present mines occur. There is, therefore, every reason to believe that in the intervening space of five hundred miles (entirely unexplored) there must be many hidden and rich deposites.

The placer gold is now substituted as currency of this country; in trade it passes freely at $16 per ounce; as an article of commerce its value is not yet fixed. The only purchase I made was of the specimen No. 7, which I got of Mr. Neligh at $12 the ounce. That is about the present cash value in the country, although it has been sold for less. The great demand for goods and provisions made by this sudden development of wealth has increased the amount of commerce at San Francisco very much, and it will continue to increase.

I would recommend that a mint be established at some eligible point on the bay of San Francisco, and that machinery, and all the apparatus and workmen, be sent by sea. These workmen must be bound by high wages, and even bonds, to secure their faithful services; else the whole plan may be frustrated by their going to the mines as soon as they arrive in California. If this course be not adopted, gold to the amount of many millions of dollars will pass yearly to other countries, to enrich their merchants and capitalists. Before leaving the subject of mines, I will mention that on my return from Sacramento, I touched at New Almoden, the quicksilver mine of Mr. Alexander Forbes, consul of her Britannic Majesty at Tepic. This mine is in a spur of mountains 1,000 feet above the level of the bay of San Francisco, and is distant in a southern direction from the Pueblo San Jose about twelve miles. The ore (cinnabar) occurs in a large vein dipping at a strong angle to the horizon. Mexican miners are employed in working it, by driving shafts and galleries about six feet by seven, following the vein.

The fragments of rock and ore are removed on the backs of Indians in rawhide sacks. The ore is then hauled in an ox wagon from the mouth of the mine down to a valley well supplied with wood and water, in which the furnaces are situated. These furnaces are of the simplest construction, exactly like a common bake-oven, in the crown of which is inserted a whaler's trying kettle; another inverted kettle forms the lid. From a hole in the lid a small brick channel leads to an apartment or chamber, in the bottom of which is inserted a small iron kettle. This chamber has a chimney.

In the morning of each day the kettles are filled with mineral, (broken in small pieces,) mixed with lime; fire is then applied, and kept up all day. The mercury, volatilized, passes into the chamber, is condensed on the sides and bottom of the chamber, and flows into the pot prepared for it. No water is used to condense the mercury.

During a visit I made last spring, four such ovens were in operation, and yielded in the two days I was there 656 pounds of quicksilver, worth at Mazatlan $1.80 per lb. Mr. Walkinshaw, the gentleman now in charge of this mine, tells me that the vein is improving, and that he can afford to keep his people employed even in these extraordinary times. This mine is very valuable of itself, and becomes the more so, as mercury is extensively used in obtaining gold. It is not at present used in California for that purpose, but will be at some future time. When I was at this mine last spring, other parties were engaged in searching for veins; but none have been discovered that are worth following up, although the earth in that whole range of hills is highly discolored, indicating the presence of this ore. I send several beautiful specimens, properly labelled. The amount of quicksilver in Mr. Forbes's vats on the 15th of July was about 25,000 pounds.

I enclose you herewith sketches of the country through which I passed, indicating the position of the mines, and the topography of the country in the vicinity of those I visited.

Some of the specimens of gold accompanying this were presented for transmission to the department by the gentlemen named below; the number on the topographical sketch, corresponding to the numbers on the labels of the respective specimens, show from what part of the gold region they were obtained:

1. Captain J. A. Sutter.
2. John Sinclair.
3. William Glover, R. C. Kirby, Ira Blanchard, Levi Fairfield, Franklin H. Ayer; Mormon diggings.
4. Chas. Weber.
5. Robert Spence.
6. Sernal & Co.
7. Robert D. Neligh.
8. C. E. Picket; American Fork, Columa.
9. E. C. Kemble.
10. T. H. Green, from San Fernando, near Los Angeles.

A. Two ounces purchased from Mr. Neligh.
B. Sand found in washing gold, which contains small particles.

11. Captain Frisbie; Dry diggings, Weber's creek.
12. Cosumnes.
13. Cosumnes; Hartnell's ranch.
14. A small specimen, supposed to be platina, found mixed with the finer particles of the gold.

I have the honor to be your obedient servant,

R. B. Mason,
Colonel 1st Dragoons, commanding

General R. Jones, *Adjutant General U.S.A., Washington, D.C.*

THE MINING OF GOLD
1849-1860

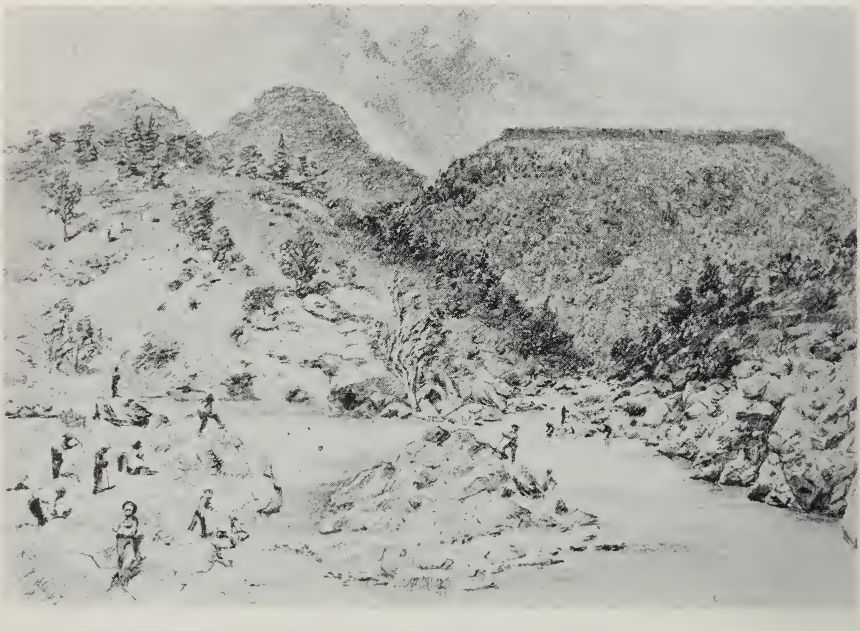


FIGURE 8. TABLE MOUNTAIN: Chappel, artist. Photo after *Pantoscope of California*, by J. Wesley Jones, by courtesy of California Historical Society, San Francisco.

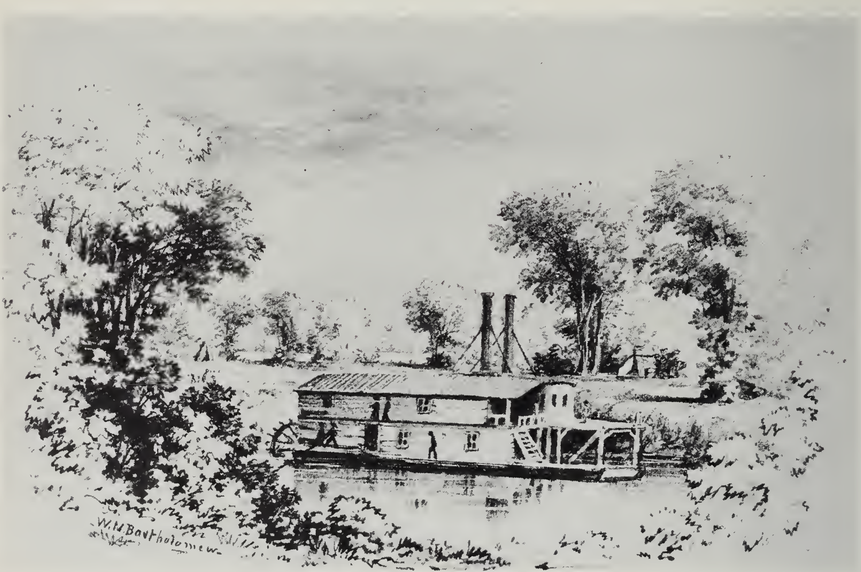


FIGURE 9. PHENIX DREDGING MACHINE, YUBA RIVER: W. N. Bartholomew, artist. Photo after *Pantoscope of California*, by J. Wesley Jones, by courtesy of California Historical Society, San Francisco.

J. WESLEY JONES' PANTOSCOPE *

The Table, or Blue Mountain on the Feather river, is as level on its summit, as a floor for very many acres in extent,—The rocky character of the streams, where gold is obtained is here faithfully represented from Daguerreotypes. You see the miners picking among the crevices in the rocks with their pick-axes and iron spoons No Light and Easy toil, "White rock" outcrops on the opposite bank, and gives name to a company,—The Captain is seen resting on his shovel, a whole souled fellow. He was formerly a wealthy merchant in New York but meeting with reverses he started for california, organized a company for throwing a dam over the Feather river and turning its channel around this bar, Here you see his men pouring water in their Cradles and washing Gold

* * * * *

The *Phenix* dredging machine is seen in the Yuba River, a cumbrous arrangement, by which it was designed to drag up sand from the bed of the river, and obtain gold in large quantities. It was soon found, however, that this machine dredged more money from the pockets of the owners than it did from the bed of the Yuba, and this kind of dredging was very soon abandoned.†

---

* In the early fifties, J. Wesley Jones made a trip across the plains and through the California mining regions to gather material for a series of illustrated lectures. On this trip, numerous daguerreotypes were made, and from them soon thereafter, a series of pencil sketches. Jones' notes and the pencil-sketch illustrations have been published in the California Historical Society Quarterly, volume 6, 1927, as *Pantoscope of California: A "Lecture" Together With Pencil Sketches Depicting the Journey Across the Plains to California.* Three of them, actual mining scenes, are reproduced herein by courtesy of the California Historical Society, with the accompaying texts.

† This was far too hasty a statement—as is well demonstrated by the U. S. Bureau of Mines figures for value of placer gold production in California during 1947:

Type of mining	Value of production
Hydraulic	$41,790
Drift	7,840
Small-scale wet	312,585
Small-scale dry	210
Non-floating washing plants	137,060
Suction dredge	16,975
Dragline dredge	931,595
Connected-bucket dredge	9,490,775

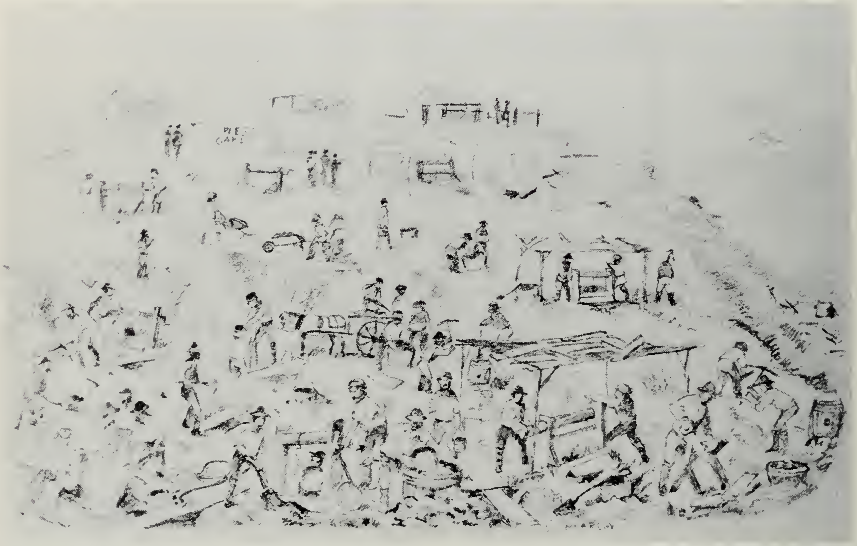


FIGURE 10. COYOTA DIGGINGS: W. Pearson, artist. Photo after *Pantoscope of California*, by J. Wesley Jones, by courtesy of California Historical Society, San Francisco.

* * * * *

All around the base of the sugar loaf Mountain the ground had been litterally torn to pieces. Deep shafts have been dug to the bed rock in every direction.

Men are seen washing in a "sluice" or long trough, along the hill side. There being a scarcity of water through the greater portion of the year, A Stock Company with a capital of $300,000 was formed, To throw a dam across Deer Creek, high up in the mountains, Thus gaining sufficient heading; through Canals, and flumes, the water is brought, often over the tree tops, to the summits of this Mountain, and branched off in a thousand different directions to supply the miners; Who are glad to get it by paying from $16 to $30 per day rentage, for enough to work their "rockers" or "toms," This being one of the most important Points in the Coyota Diggings, We stopped here some time, informing the miners of our intentions, With great Kindness they retained their position, and you have them as nearly as possible at their several occupations. One is preparing the "timbers" with which to bridge the claim, For having sunk a shaft to the bed rock, They then drift out on either side, following the gold seams, and these timbers are let down, so halved together, as to prevent the possibility of caving in. Inattention to this matter has cost the lives of Many Miners on this Hill side. Some are shoveling up the auriferous earth, while another is going down with a torch to light the "claim" or blast out the rocks.

On the left men are washing in a "*sluice*" This differs from a "long tom" only in its greater length a hundred men, may work along it, shoveling in the dirt, and stones, Which are stirred up, until the torrent washes everything away but the gold, and a very heavy black sand; Which always settles with it; and requires another process to remove it, "*Panning out*" one is here seen at a tub, and by a gentle swelling motion in and out of the water, he soon floats away the Sand, Leaving the Gold in the bottom of the Pan fit for the Market, and Mint.

J. D. BORTHWICK "SEES THE ELEPHANT" *

When about ten miles from the plains [en route from Sacramento to Placerville], I first saw the actual reality of gold-digging. Four or five men were working in a ravine by the roadside, digging holes like so many grave-diggers. I then considered myself fairly in "the mines", and experienced a disagreeable consciousness that we might be passing over huge masses of gold, only concealed from us by an inch or two of earth.

For several miles again the country would seem to be deserted. That it had once been a busy scene was evident from the uptorn earth in the ravines and hollows, and from the numbers of unoccupied cabins; but the cream of such diggings had already been taken, and they were not now sufficiently rich to suit the ambitious ideas of the miners.

* * * * *

The diggings here (at Hangtown, now Placerville) had been exceedingly rich—men used to pick the chunks of gold out of the crevices of the rocks in the ravines with no other tool than a bowie-knife; but these days had passed, and now the whole surface of the surrounding country showed the amount of real hard work which had been done. The beds of the numerous ravines which wrinkle the faces of the hills, the bed of the creek, and all the little flats alongside of it, were a confused mass of heaps of dirt and piles of stones lying around the innumerable holes, about six feet square and five or six feet deep, from which they had been thrown out. The original course of the creek was completely obliterated, its waters being distributed into numberless little ditches, and from them conducted into the "long toms" of the miners through canvass hoses, looking like immensely long slimy sea-serpents.

* * * * *

Along the whole length of the creek (at Hangtown), as far as one could see, on the banks of the creek, in the ravines, in the middle of the principal and only street of the town, and even inside some of the houses, were parties of miners, numbering from three or four to a dozen, all hard at work, some laying into it with picks, some shovelling the dirt into "long toms", or with long-handled shovels washing the dirt thrown in, and throwing out the stones, while others were working pumps or baling water out of the holes with buckets. There was a continual noise and clatter, as mud, dirt, stones, and water were thrown about in all directions; and the men, dressed in ragged clothes and big boots, wielding picks and shovels, and rolling big rocks about, were all working as if for their lives, going into it with a will, and a degree of energy, not usually seen among labouring men. It was altogether a scene which conveyed the idea of hard work in the fullest sense of the words, and in comparison with which a gang of railway navvies would have seemed to be merely a party of gentlemen amaturs playing at working *pour passer le temps.*

* * * * *

Here and there, in the middle of the street (in Hangtown), was a square hole about six feet deep, in which one miner was digging, while another was baling the water out with a bucket, and a third, sitting alongside the heap of dirt which had been dug up, was washing it in a rocker.

---

* In 1851, J. D. Borthwick left New York City and journeyed by way of the Isthmus of Panama to the California gold fields. There he tried his hand at mining—but found that he could collect gold-dust just as swiftly and much more comfortably in another way— drawing pictures for miners. An account of his travels, which were quite extensive, taking him to both the northern and southern diggings, was published as *Three Years in California*, by William Blackford & Sons of Edinburgh, in 1857. Figures 11, 12, and 13, and the text matter are reprinted from that book.

* * * * *

The richest deposits of gold were found in the beds and banks of the rivers, creeks, and ravines, in the flats on the convex side of the bends of the streams, and in many of the flats and hollows high up in the mountains. The precious metal was also abstracted from the very hearts of the mountains, through tunnels drifted into them for several hundred yards; and in some places real mining was carried on in the bowels of the earth by means of shafts sunk to the depth of a couple of hundred feet.

The principal diggings in the neighbourhood of Hangtown were surface diggings; but, with the exception of river diggings, every kind of mining operation was to be seen in full force.

The gold is found at various depths from the surface; but the dirt on the bed-rock is the richest, as the gold naturally in time sinks through earth and gravel, till it is arrested in its downward progress by the solid rock.

The diggings here were from four to six or seven feet deep; the layer of "pay-dirt" being about a couple of feet thick on the top of the bed-rock.

I should mention that "dirt" is the word universally used in California to signify the substance dug, earth, clay, gravel, loose slate, or whatever other name might be more appropriate. The miners talk of rich dirt and poor dirt, and of "stripping off" so many feet of "top dirt" before getting to "pay dirt", the latter meaning dirt with so much gold in it that it will pay to dig it up and wash it.

The apparatus generally used for washing was a "long tom", which was nothing more than a wooden trough from twelve to twenty-five feet long, and about a foot wide. At the lower end it widens considerably, and the floor of it is there a sheet of iron pierced with holes half an inch in diameter, under which is placed a flat box a couple of inches deep. The long tom is set at a slight inclination over the place which is to be worked, and a stream of water is kept running through it by means of a hose, the mouth of which is inserted in a dam built for the purpose high enough up the stream to gain the requisite elevation; and while some of the party shovel the dirt into the tom as fast as they can dig it up, one man stands at the lower end stirring up the dirt as it is washed down, separating the stones and throwing them out, while the earth and small gravel falls with the water through the sieve into the "ripple-box". This box is about five feet long, and is crossed by two partitions. It is also placed at an inclination, so that the water falling into it keeps the dirt loose, allowing the gold and heavy particles to settle to the bottom, while all the lighter stuff washes over the end of the box along with the water. When the day's work is over, the dirt is taken from the "ripple-box" and is "washed out" in a "wash-pan", a round tin dish, eighteen inches in diameter, with shelving sides three or four inches deep. In washing out a panful of dirt, it has to be placed in water deep enough to cover it over; the dirt is stirred up with the hands, and the gravel thrown out; the pan is then taken in both hands, and by an indescribable series of manoeuvers all the dirt is gradually washed out of it, leaving nothing but the gold and a small quantity of black sand. This black sand is mineral (some oxide or other salt of iron), and is so heavy that it is not possible to wash it all out; it has to be blown out of the gold afterwards when dry.

Another mode of washing dirt, but much more tedious, and consequently only resorted to where a sufficient supply of water for a long tom could not be obtained, was by means of an apparatus called a "rocker" or "cradle". This was merely a wooden cradle, on the top of which was a sieve. The dirt was put into this, and a miner, sitting alongside of it, rocked the cradle with one hand, while with a dipper in the other he kept baling water on to the dirt. This acted on the same principle as the "tom", and had formerly been the only contrivance in use; but it was now seldom seen, as the long tom effected such a saving of time and labour. The latter was set immediately over the claim, and the dirt was shovelled into it at once, while a rocker had to be set alongside of the water, and the dirt was carried to it in buckets from the place which was being worked. Three men working together with a rocker—one digging, another carrying the dirt in buckets, and the third rocking the cradle—could wash on an average a hundred bucketfuls of dirt to the man in the course of the day. With a "long tom" the dirt was so easily washed that parties of six or eight could work together to advantage, and four or five hundred bucketfuls of dirt a-day to each one of the party was a usual day's work.

* * * * *

A "prospector" goes out with a pick and shovel, and a wash-pan; and to test the richness of a place he digs down till he reaches the dirt in which it may be expected that the gold will be found; and washing out a panful of this, he can easily calculate, from the amount of gold which he finds in it, how much could be taken out in a day's work. An old miner, looking at the few specks of gold in the bottom of his pan, can tell their value within a few cents; calling it a twelve or a twenty cent "prospect", as it may be. If, on washing out a panful of dirt, a mere speck of gold remained, just enough to swear by, such dirt was said to have only "the colour", and was not worth digging. A twelve-cent prospect was considered a pretty good one; but in estimating the probable result of a day's work, allowance had to be made for the time and labour to be expended in removing top-dirt, and in otherwise preparing the claim for being worked.

To establish one's claim to a piece of ground, all that was requisite was to have upon it a pick or shovel, or other mining tool. The extent of ground allowed to each individual varied in different diggings from ten to thirty feet square, and was fixed by the miners themselves, who also made their own laws, defining the rights and duties of those holding claims; and any dispute on such subjects was settled by calling together a few of the neighbouring miners, who would enforce the due observance of the laws of the diggings.

* * * * *

Very near where we were at work, a party of half-a-dozen men held a claim in the bed of the creek, and had as usual dug a race through which to turn the water, and so leave exposed the part they intended to work. This they were now anxious to do, as the creek had fallen sufficiently low to admit of it; but they were opposed by a number of miners whose claims lay so near the race that they would have been swamped had the water been turned into it.

They could not come to any settlement of the question among themselves; so, as was usual in such cases, they concluded to leave it to a jury of miners; and notice was accordingly sent to all the miners within two or three miles up and down the creek, requesting them to assemble on the claim in question the next afternoon. Although a miner calculates an hour lost as so much money out of his pocket, yet all were interested in supporting the laws of the diggings; and about a hundred men presented themselves at the appointed time. The two opposing parties then, having tossed up for the first pick, chose six jurymen each from the assembled crowd.

When the jury had squatted themselves all together in an exalted position on a heap of stones and dirt, one of the plaintiffs, as spokesman for his party, made a very pithy speech, calling several witnesses to prove his statements, and citing many of the laws of the diggings in support of his claims. The defendants followed in the same manner, making the most of their case; while the general public, sitting in groups on the different heaps of stones piled up between the holes with which the ground was honeycombed, smoked their pipes, and watched the proceedings.

After the plaintiff and defendant had said all they had to say about it, the jury examined the state of the ground in dispute; they then called some more witnesses to give further information, and having laid their shaggy heads together for a few minutes, they pronounced their decision; which was, that the men working on the race should be allowed six days to work out their claims before the water should be turned in upon them.

Neither party were particularly well pleased with the verdict—a pretty good sign that it was an impartial one; but they had to abide by it, for had there been any resistance on either side, the rest of the miners would have enforced the decision of this august tribunal. From it there was no appeal; a jury of miners was the highest court known, and I must say I never saw a court of justice with so little humbug about it.

* * * * *

We arrived at Nevada City between five and six o'clock. . . . As I had half an hour to wait for supper, I strolled about the town to see what sort of a place it was. It is beautifully situated on the hills bordering a small creek, and has once been surrounded by a forest of magnificent pine-trees, which, however, had been made to become useful instead of ornamental, and nothing now remained to show that they had existed but the numbers of stumps all over the hill-sides. The bed of the creek, which had once flowed past the town, was now choked up with heaps of "trailings"—the washed dirt from which the gold has been extracted—the white colour of the dirt rendering it still more unsightly. All the water of the creek was distributed among a number of small troughs, carried along the steep banks on either side at different elevations, for the purpose of supplying various quartz-mills and long-toms.

The town itself—or, I should say, the "City", for from the moment of its birth it has been called Nevada City—is, like all mining towns, a mixture of staring white frame-houses, dingy old canvass booths, and log-cabins.

The only peculiarity about the miners was the white mud with which they were bespattered, especially those working in underground diggings, who were easily distinguished by the quantity of dry white mud on the tops of their hats.

* * * * *

. . . "Coyote" diggings [receive] their name from an animal called the "coyote", which abounds all over the plain lands of Mexico and California, and which lives in the cracks and crevices made in the plains by the extreme heat of summer. . . .

These coyote diggings require to be very rich to pay, from the great amount of labour necessary before any pay-dirt can be obtained. They are generally worked by only two men. A shaft is sunk, over which is rigged a crude windlass, tended by one man, who draws up the dirt in a large bucket while his partner is digging down below. When the bed rock is reached on which the rich dirt is found, excavations are made all round, leaving only the necessary supporting pillars of earth, which are also ultimately removed, and replaced by logs of wood. Accidents frequently occur from the "caving-in" of these diggings, the result generally of the carelessness of the men themselves.

The Cornish miners, of whom numbers had come to California from the mines of Mexico and South America, generally devoted themselves to these deep diggings, as did also the lead-miners from Wisconsin. Such men were quite at home a hundred feet or so under ground, picking through hard rock by candle-light; at the same time, gold mining in any way was to almost every one a new occupation, and men who had passed their lives hitherto above ground, took quite as naturally to this subterranean style of digging as to any other.

* * * * *

On leaving Foster's Bar, I went to a place a few miles up the river, where some miners were at work who had asked me to visit their camp. The river here flowed through a narrow rocky gorge (a sort of place which, in California, is called by its Spanish name a "cañon"), and was flumed for a distance of nearly half a mile; that is to say, it was carried past in an aqueduct supported on uprights, being raised from its natural bed, which was thus laid bare and rendered capable of being worked. . . .

Within a few feet of us . . . the river rushed past in its wooden bed, spinning round, as it went, a large water-wheel, by means of which a constant stream of water was pumped up from the diggings and carried off in the flume.

* * * * *

Without having visited some distant place in the mountains, such as Downieville, it was impossible to realise fully the extraordinary extent to which the country had, in so short a time, been overrun and settled by a population whose energy and adaptive genius had immediately seized and improved every natural advantage which presented itself, and whose quickly acquired wealth enabled them to introduce so much luxury, and to afford employment to so many of those branches of industry which usually flourish only in old communities, that in some respects California can hardly be said to have ever been a new country, as compared with other parts of the world to which that term is applied.

The men who settled the country imparted to it a good deal of their own nature, which knows no period of boyhood. The Americans spring at once from childhood, or almost infancy, to manhood; and California, no less rapid in its growth, became a full-grown State, while one-half of the world still doubted its existence.

The amount of labour which had already been performed in the mines was almost incredible. Every river and creek from one end to the other presented a busy scene; on the "bars" of course, the miners were congregated in the greatest numbers; but there was scarcely any part of their course where some work was not going on, and the flumes were so numerous, that for about one-third of their length the rivers were carried past in those wooden aqueducts.

The most populous part of the mines, however, was in the high mountain-land between the rivers, and here the whole country had been ransacked, every flat and ravine had been prospected; and wherever extensive diggings had been found, towns and villages had sprung up.

Young as California was, it was in one respect older than its parent country, for life was so fast that already it could show ruins and deserted villages. In out-of-the-way places one met with cabins fallen into disrepair, which the prospectors had abandoned to locate themselves elsewhere; and even villages of thirty or forty shanties were to be seen deserted and desolate, where the diggings had not proved so productive as the original founders had anticipated.

Labour, however, was not exclusively devoted to mining operations. Roads had in many parts been cut in the sides of the mountains, bridges had been built, and innumerable saw-mills, most of them driven by steam-power, were in full operation, many of them having been erected in anticipation of a demand for lumber, and before any population existed around them. Every little valley in the mountains where the soil was at all fit for cultivation was already fenced in, and producing crops of barley or oats; and canals, in some cases forty or fifty

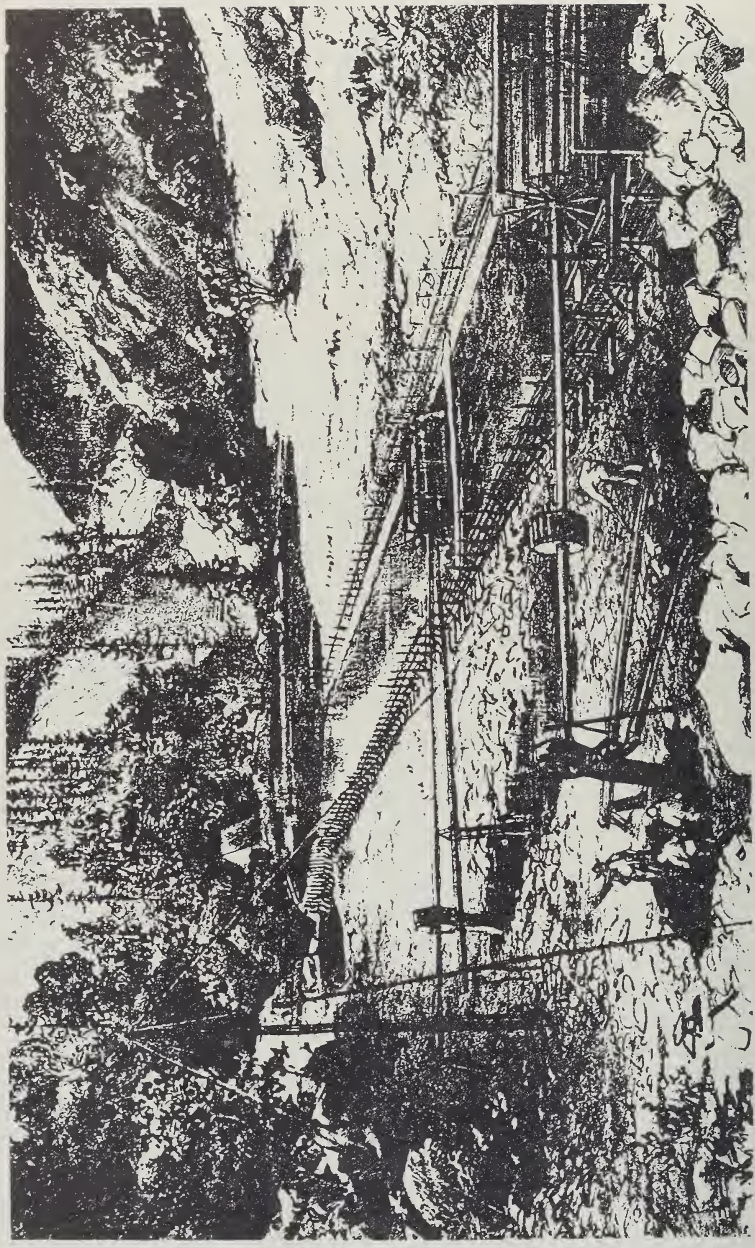


FIGURE 11. A FLUME ON THE YUBA RIVER: J. D. Borthwick, delt., M & N Hanhart, Impt. Published in *Three Years in California*, by J. D. Borthwick, 1857. Photo after *Pictorial History of California* by Owen C. Coy, by courtesy of University of California Extension Division, Berkeley, and Wells Fargo Bank & Union Trust Co., San Francisco.

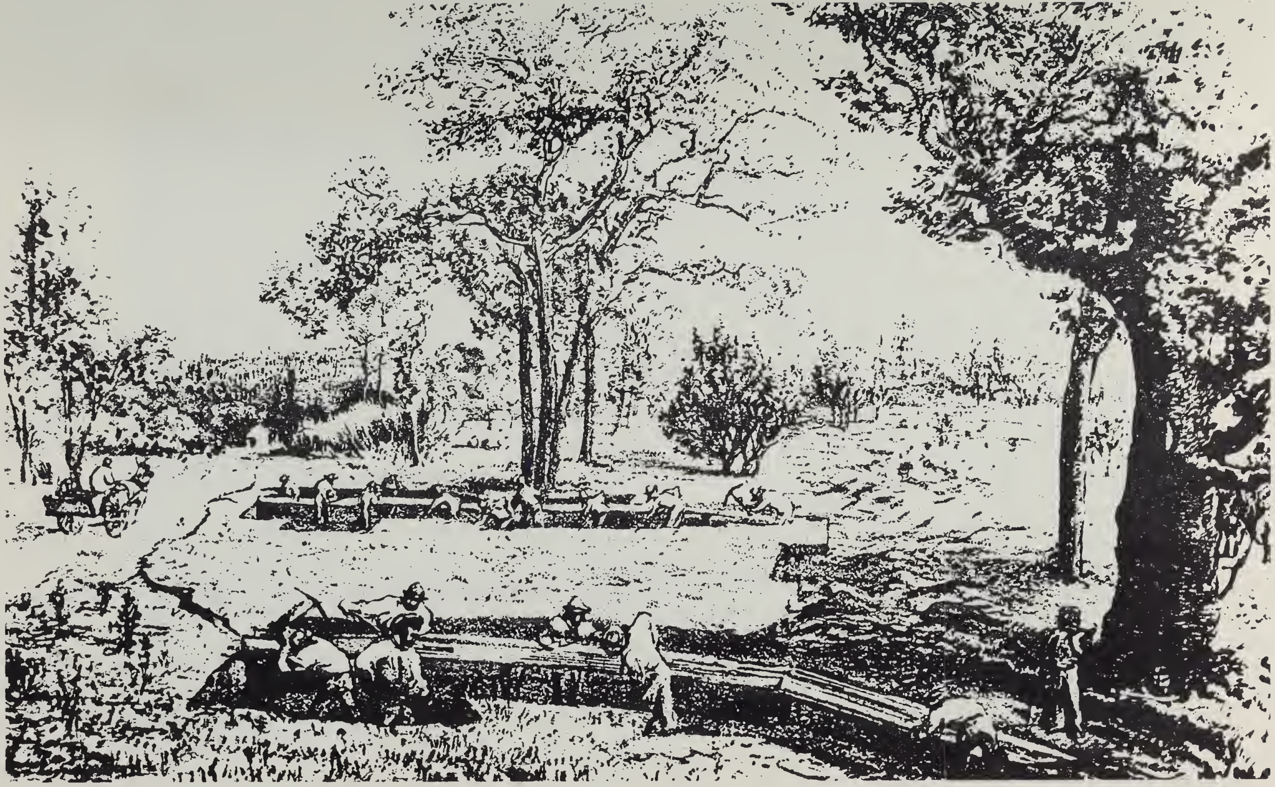


FIGURE 12. SHAW'S FLATS: J. D. Borthwick, Delt.; M & N Hanhart, Lith. Photo after *Three Years in California*, by J. D. Borthwick, 1857, by courtesy of California Historical Society, San Francisco.

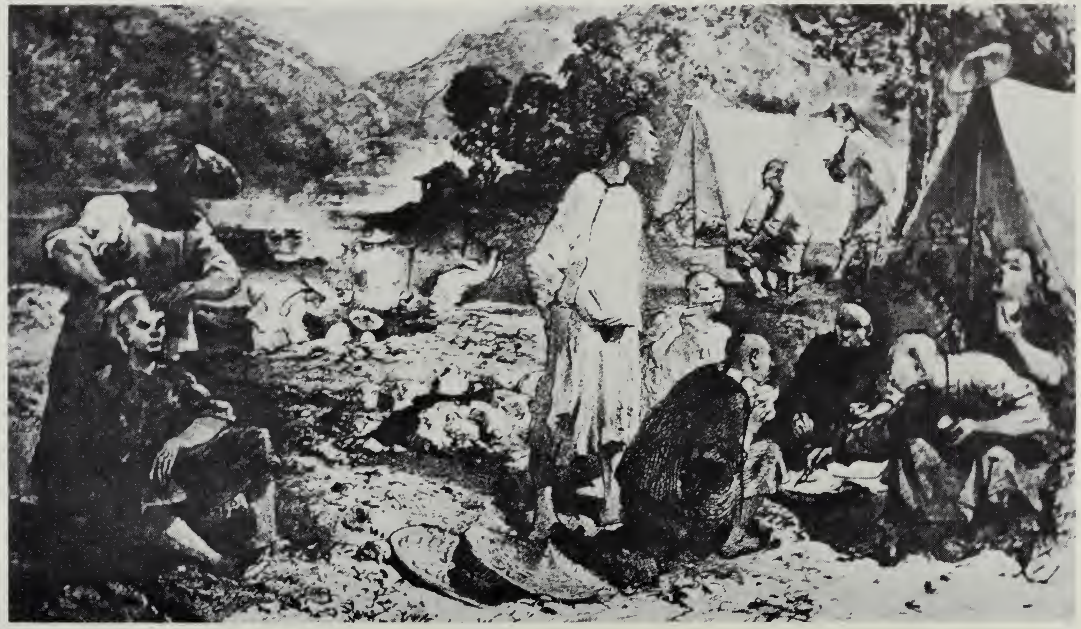


FIGURE 13. CHINESE CAMP IN THE MINES: J. D. Borthwick, delt.; M & N Hanhart, lith. Poho after *Three Years in California*, by J. D. Borthwick, 1857, by courtesy of California Historical Society, San Francisco.

miles long, were in course of construction, to bring the waters of the rivers to the mountain-tops, to diggings which were otherwise unavailable.

* * * * *

These [arrastres] are the most primitive kind of contrivance for grinding quartz. They are circular places, ten or twelve feet in diameter, flagged with flat stones, and in these the quartz is crushed by two large heavy stones dragged round and round by a mule harnessed to a horizontal beam, to which they are also attached.

The quartz is already broken up into small pieces before being put into the raster, and a constant supply of water is necessary to facilitate the operation, the stuff, while being ground, having the appearance of a rich white mud. The Mexicans, who use this machine a great deal, have a way of ascertaining when the quartz is sufficiently ground, by feeling it between the finger and thumb of one hand, while with the other they feel the lower part of their ear; and when the quartz has the same soft velvety feel, it is considered fine enough, and the gold is then extracted by amalgamation with quicksilver.

* * * * *

A break in this long narrow Table Mountain was formed by a place called Shaw's Flats, a wide extent of perfectly flat country, four or five miles across, well wooded with oaks, and plentifully sprinkled over with miners' tents and shanties.

The diggings were rich. The gold was very coarse, and frequently found in large lumps; but how it got there was not easy to conjecture, for the flat was on a level with Table Mountain, and hollows intervened between it and any higher ground. Mining here was quite a clean and easy operation. Any old gentleman might have gone in and taken a turn at it for an hour or two before dinner just to give him an appetite, without even wetting the soles of his boots: indeed, he might have fancied he was only digging in his garden, for the gold was found in the very roots of the grass, and in most parts there was only a depth of three or four feet from the surface to the bed-rock, which was of singular character, being . . . full of circular cavities and presenting all manner of fantistic forms, caused apparently by the long-continued action of water in rapid motion.

* * * * *

They [the Chinese] are an industrious set of people, no doubt, but are certainly not calculated for gold-digging. They do not work with the same force or vigour as American or European miners, but handle their tools like so many women, as if they were afraid of hurting themselves. The Americans call it "scratching" which was a very expressive term for their style of digging. They did not venture to assert equal rights so far as to take up any claim which other miners would think it worth while to work; but in such places as yielded them a dollar or two a-day they were allowed to scratch away unmolested. Had they happened to strike a rich lead, they would have been driven off their claim immediately. They were very averse to working in the water, and for four or five hours in the heat of the day they assembled under the shade of a tree, where they sat fanning themselves, drinking tea, and saying "too muchee hot". . . .

* * * * *

There were about a hundred and fifty of them here [Mississippi Bar], living in a perfect village of small tents, all clustered together on the rocks. They had a claim in the bed of the river, which they were working by means of a wing dam. A "wing dam", I may here mention, is one which first runs half-way across the river, then down the river, and back again to the same side, thus damming off a portion of its bed without the necessity of the more expensive operation of lifting up the whole river bodily in a "flume".

The Chinamen's dam was two or three hundred yards in length, and was built of large pine-trees laid one on the top of the other. They must have had great difficulty in handling such immense logs in such a place; but they are exceedingly ingenious in applying mechanical power, particularly in concentrating the force of a large number of men upon one point.

This claim on the Yuba was the greatest undertaking I ever saw attempted by them.

They expended a vast deal of unnecessary labour in their method of working, and their individual labour, in effect, was as nothing compared with that of other miners. A company of fifteen or twenty white men would have wing-dammed this claim, and worked it out in two or three months, while here were about a hundred and fifty Chinamen humbugging round it all the season, and still had not worked one half the ground.

Their mechanical contrivances were not in the usual rough straightforward style of the mines; they were curious, and very elaborately got up, but extremely wasteful of labour, and, moreover, very ineffective.

The pumps which they had at work here were an instance of this. They were on the principle of a chain-pump, the chain being formed of pieces of wood about six inches long, hinging on each other, with cross-pieces in the middle for buckets, having about six square inches of surface. The hinges fitted exactly to the spokes of a small wheel, which was turned by a Chinaman at each side of it working a miniature treadmill of four spokes on the same axle. As specimens of joiner-work they were very pretty, but as pumps they were ridiculous; they threw a mere driblet of water: the chain was not even encased in a box—it merely lay in a slanting trough, so that more than one half the capacity of the buckets was lost. An American miner, at the expenditure of one-tenth part of the labour of making such toys, would have set a water-wheel in the river to work an elevating pump, which would have thrown more water in half an hour than four-and-twenty Chinamen could throw in a day with a dozen of these gim-crack contrivances.

* * * * *

Although the severity of the weather interrupted mining operations for the time, it was nevertheless a subject of rejoicing to the miners generally, for many localities could only be worked when plenty of water was running in the ravines, and it was not unusual for men to employ themselves in the dry season in "throwing up" heaps of dirt, in anticipation of having plenty of water in winter to wash it. This was commonly done in flats and ravines where water could only be had immediately after heavy rains. It was easy to distinguish a heap of thrown-up dirt from a pile of "tailings," or dirt already washed, and property of this sort was quite sacred, the gold being not less safe there—perhaps safer—than if already in the pocket of the owner. In whatever place a man threw up a pile of dirt, he might leave it without any concern for its safety, and remove to another part of the country, being sure to find it intact when he returned to wash it, no matter how long he might be absent.

* * * * *

The want of water was the great obstacle in the way of mining at Moquelumne Hill. As it stood so much higher than the surrounding country, there were no streams which could be introduced, and the only means of getting a constant supply was to bring the water from the Moquelumne River, which flowed past, three or four thousand feet below the diggings. In order to get the requisite elevation to raise the waters so far above their natural channel, it was found necessary to commence the canal some fifty or sixty miles up the river. The idea had been projected, but the execution of such a piece of work required more capital than could be raised at the moment; but the diggings at Moquelumne Hill were known to be so rich, as was also the tract of country through which the canal would pass, that the speculation was considered sure to be successful; and a company was not long after formed for the purpose of carrying out the undertaking, which amply repaid those embarked in it, and opened up a vast extent of new field for mining operations, by supplying water in places which otherwise could only have been worked for two or three months of the year.

This was only one of many such undertakings in California, some of which were even on a larger scale. The engineering difficulties were very great, from the rocky and mountainous nature of the country through which the canals were brought. Hollows and valleys were spanned at a great height by aqueducts, supported on graceful scaffolding of pine logs, and precipitous mountains were girded by wooden flumes projecting from their rocky sides. Throughout the course of a canal, wherever water was wanted by miners, it was supplied to them at so much an inch, a sufficient quantity for a party of five or six men costing about seven dollars a-day.

* * * * *

The principal diggings at Volcano are in the banks of a gulch, called Soldiers' Gulch, from its having been first worked by United States' soldiers, and were of a peculiar nature, differing from any other diggings I had seen, inasmuch as, though they had been worked to a depth of forty or fifty feet from the surface, they had been equally rich from top to bottom, and as yet no bed-rock had been reached. It was seldom such a depth of pay-dirt was found. The gold was usually only found within a few feet of the bottom, but in this case the stiff clay soil may have retained the gold, and prevented its settling down so readily as through sand or gravel. The clay was so stiff that it was with difficulty it could be washed, and lately the miners had taken to boiling it in large boilers, which was found to dissolve it very quickly.

* * * * *

The southern mines . . . were full of all sorts of people. There were many villages peopled nearly altogether by Mexicans, others by Frenchmen; in some places there were parties of two or three hundred Chilians forming a community of their own. The Chinese camps were very numerous; and besides all such distinct colonies of foreigners, every town of the southern mines contained a very large foreign population. The Americans, however, were of course greatly the majority, but even among them one remarked the comparatively small number of Missourians and such men, who are so conspicuous in the north.

There was still another difference [between the northern and southern mines] in a very important feature—in fact, the most important of all—the gold. The gold of the northern mines is generally flaky, in exceedingly small thin scales; that of the south is coarse gold, round and "chunky." The rivers of the north afford very rich diggings, while in the south they are comparatively poor, and the richest deposits are found in flats and other surface-diggings on the highlands.

* * * * *

I went on the next morning to San Andres by a road which winded through beautiful little valleys, still fresh and green, and covered with large patches of flowers. In one long gulch through which I passed, about two hundred Chilians were at work washing the dirt, panful by panful, in their large flat wooden dishes. This is a very tedious process, and a most unprofitable expenditure of labour; but Mexicans, Chilians, and other Spanish Americans, most obstinately adhere to their old-fashioned primitive style, although they had the example before them of all the rest of the world continually making improvements in the method of abstracting the gold, whereby time was saved and labour rendered tenfold more effective.

* * * * *

From Angel's Camp I went on a few miles to Carson's Creek, on which there was a small camp lying at the foot of a hill, which was named after the same man. On its summit a quartz vein cropped out in large masses to the height of thirty or forty feet, looking at a distance like the remains of a solid wall of fortification. It had only been worked a few feet from the surface, but already an incredible amount of gold had been taken out.

Every place in the mines had its traditions of wonderful events which had occurred in the olden times; that is to say, as far back as "'49"—for three years in such a fast country were equal to a century; and at this place the tradition was, that, when the quartz vein was first worked, the method adopted was to put in a blast, and after the explosion, to go round with handbaskets and pick up the pieces. I believe this was only a slight exaggeration of the truth, for at this particular part of the vein there had been found what is there called a "pocket", a spot not more than a few feet in extent, where lumps of gold in unusual quantities lie imbedded in the rock. No systematic plan had been followed in opening the mine with a view to the proper working of it; but several irregular excavations had been made in the rock wherever the miners had found the gold most plentiful. For nearly a year it had not been worked at all, in consequence of several disputes as to the ownership of the claims; and in the mean time the lawyers were the only two parties who were making anything out of it.

On the other side of the hill, however, was a claim on the same vein, which was in undisputed possession of a company of Americans, who employed a number of Mexicans to work it, under the direction of an experienced old Mexican miner. They had three shafts sunk in the solid rock, in a line with each other, to the depth of two hundred feet, from which galleries extended at different points, where the gold-bearing quartz was found in the greatest abundance. No ropes or windlasses were used for descending the shafts; but at every thirty feet or so there was a sort of step or platform, resting on which was a pole with a number of notches cut all down one side of it; and the rock excavated in the various parts of the mine was brought up in leathern sacks on men's shoulders, who had to make the ascent by climbing a succession of these poles. The quartz was then conveyed on pack-mules down to the river by a circuitous trail, which had been cut on the steep side of the mountain, and was there ground in the primitive Mexican style in "rasters". The whole operation seemed to be conducted at a most unnecessary expenditure of labour; but the mine was rich, and, even worked in this way, it yielded largely to the owners.

Numerous small wooden crosses were placed throughout the mine, in niches cut in the rock for their reception, and each separate part of the mine was named after a saint who was supposed to take those working in it under his immediate protection. The day before I visited the place had been some saint's day, and the Mexicans, who of course had made a holiday of it, had employed themselves in erecting, on the side of the hill over the mine, a large cross, about ten feet high, and had completely clothed it with the beautiful wildflowers which grew around in the greatest profusion. In fact, it was a gigantic cruciform nosegay, the various colours of which were arranged with a great deal of taste.

The mine is on the great quartz vein which traverses the whole State of California. It has a direction north-east and south-west, perfectly true by compass; and from many points where an extensive view of the country is obtained, it can be distinctly traced for a great distance as it "crops out" here and there, running up a hill-side like a colossal stone wall, and then disappearing for many miles, till, true to its course, it again shows itself crowning the summit of some conical-shaped mountain, and appearing in the distant view like so many short white strokes, all forming part of the same straight line.

The general belief was that at one time all the gold in the country had been imbedded in quartz, which, being decomposed by the action of the elements, had set the gold at liberty, to be washed away with other debris, and to find a resting-place for itself. Rich diggings were frequently found in the neighborhood of quartz veins, but not invariably so, for different local causes must have operated to assist the gold in travelling from its original starting-point.

As a general rule, the richest diggings seemed to be in the rivers at those points where the eddies gave the gold an opportunity of settling down instead or being borne further along by the current, or in those places on the highlands where, owing to the flatness of the surface or the want of egress, the debris had been retained while the water ran off; for the first idea one formed from the appearance of the mountains was, that they had been very severely washed down, but that there had been sufficient earth and debris to cover their nakedness, and to modify the sharp angularity of their formation.

* * * * *

People now began to venture down upon the still smoking site of the city [Sonora], and, seeing an excitement among them at the lower end of the town, I went down to see what was going on. The atmosphere was smoky and stifling, and the ground was almost too hot to stand on. The crowd was collected on a place which was known to be very rich, as the ground behind the houses had been worked, and a large amount of gold having been there extracted, it was consequently presumed that under the houses equally good diggings would be found. During the fire, miners had flocked in from all quarters, and among them were some unprincipled vagabonds, who were now endeavouring to take up mining claims on the ground where the houses had stood, measuring off the regular number of feet allowed to each man, and driving in stakes to mark out their claims in the usual manner.

The owners of the houses, however, were "on hand", prepared to defend their rights to the utmost. Men who had just seen the greater part of their property destroyed were not likely to relinquish very readily what little still remained to them; and now, armed with pistols, guns, and knives, their eyes bloodshot and their faces scorched and blackened, they were tearing up the stakes as fast as the miners drove them in, while they declared very emphatically, with all sorts of oaths, that any man who dared to put a pick into that ground would not live half a minute. And truly a threat from such a man was one not to be disregarded.

By the laws of the mines, the diggings under a man's house are his property, and the law being on their side, the people would have assisted them in defending their rights; and it would not have been absolutely necessary for them to take the trouble of shooting the miscreants, who, as other miners began to assemble on the ground, attracted by the row, found themselves so heartily denounced that they thought it advisable to sneak off as fast as possible.

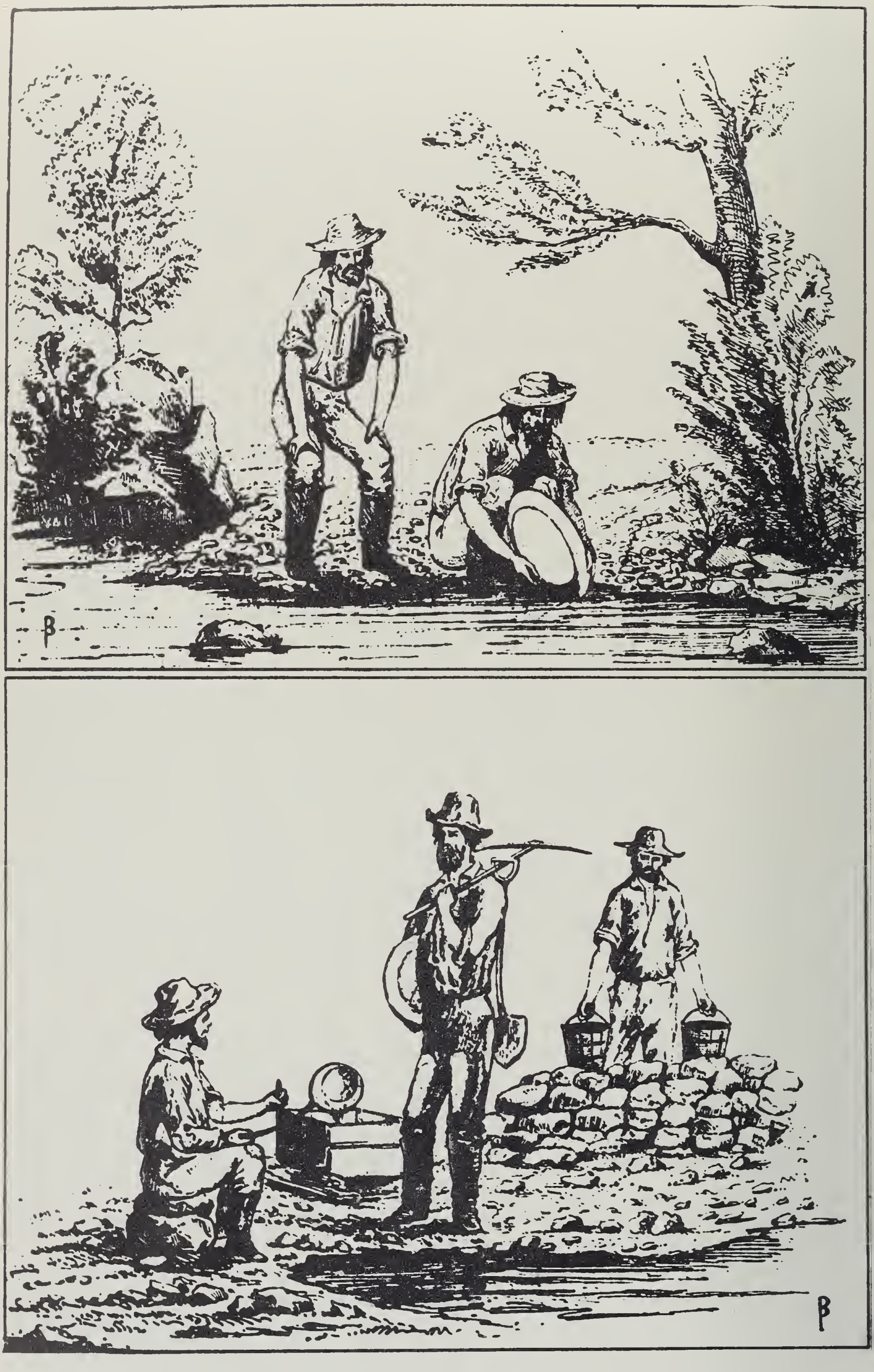


FIGURE 14. FOUR MINING SCENES: Lithograph of Quirot & Co., California St. Corn. Montgomery St., S-Francisco.

Photo by courtesy of Sutter's Fort Historical Museum, Sacramento.

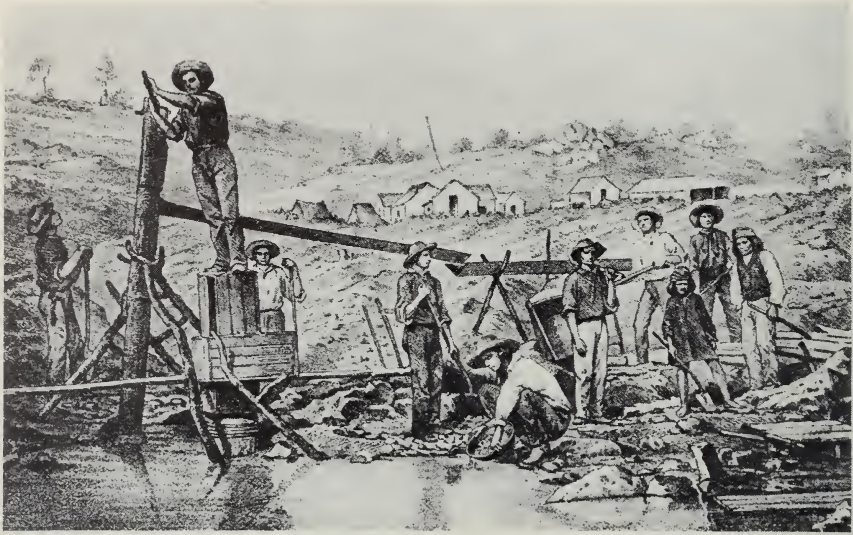


FIGURE 15. THE MINERS: Lith. & publ. by Britton & Rey, San Francisco. Photo by courtesy of Sutter's Fort Historical Museum, Sacramento.

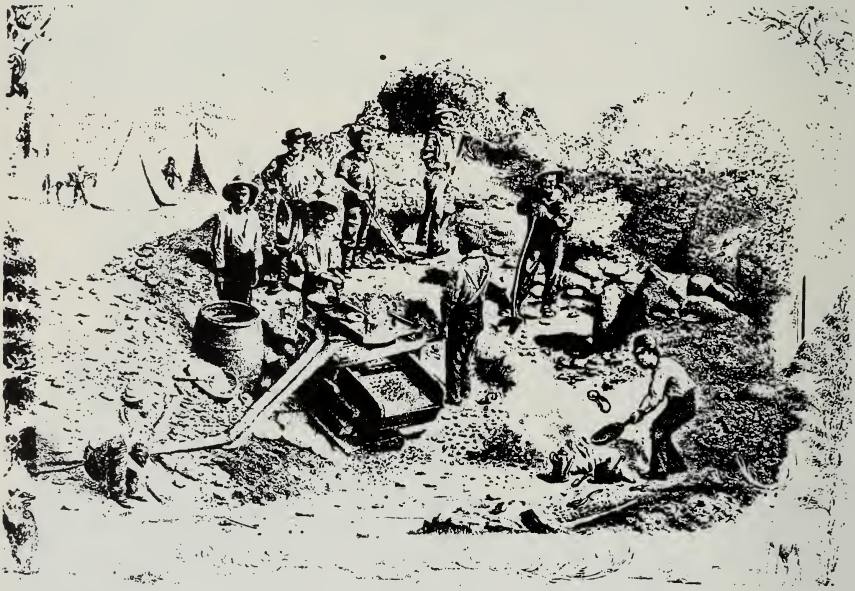


FIGURE 16. LIFE IN THE GOLD MINES, CALIFORNIA: Lithographed from a Photograph by Fishbourne & Gow, San Francisco; published by Martin & Hitchcock. Photo by courtesy of Society of California Pioneers, San Francisco.

MINING FOR GOLD IN CALIFORNIA *

The reader no doubt well remembers the peculiar impressions which the first tidings of the discovery of gold in California produced upon his mind. How in every possible way the imagination industriously endeavored to picture the exhilarating scenes which surrounded, and the pleasurable excitement which attended the enviable employment of digging for gold. What lucky fellows they must be, who, untrammeled by the common-place constraint of ordinary business, could, with their own hands, take the precious metal from the earth, and in a few brief months, perhaps, by their own labor, become the fortunate possessors of sufficient wealth to make a whole lifetime happy for themselves and family, as well as useful to others.

What enchanting visions of the good to be accomplished—of the pleasures to be enjoyed—of the greatness to be achieved,—or the triumphs to be won, influenced his decision and turned his thoughts and footsteps toward the Land of Gold.

No wonder that his impressions were somewhat vague, and his knowledge limited and indefinite; as but little was then known of the country, manner of living, and labor required or methods in use for working the mines. Even to this day, with all that has been written, and all the pictorial illustrations which have been published, those who have not actually visited the mines, have but a very incorrect conception of what they are, or how they are worked.

We therefore believe that the reader—be he ever so familiar with everything appertaining to mining and mining life—will be the better pleased should our description of each and every method and implement be simple, and easy to be understood.

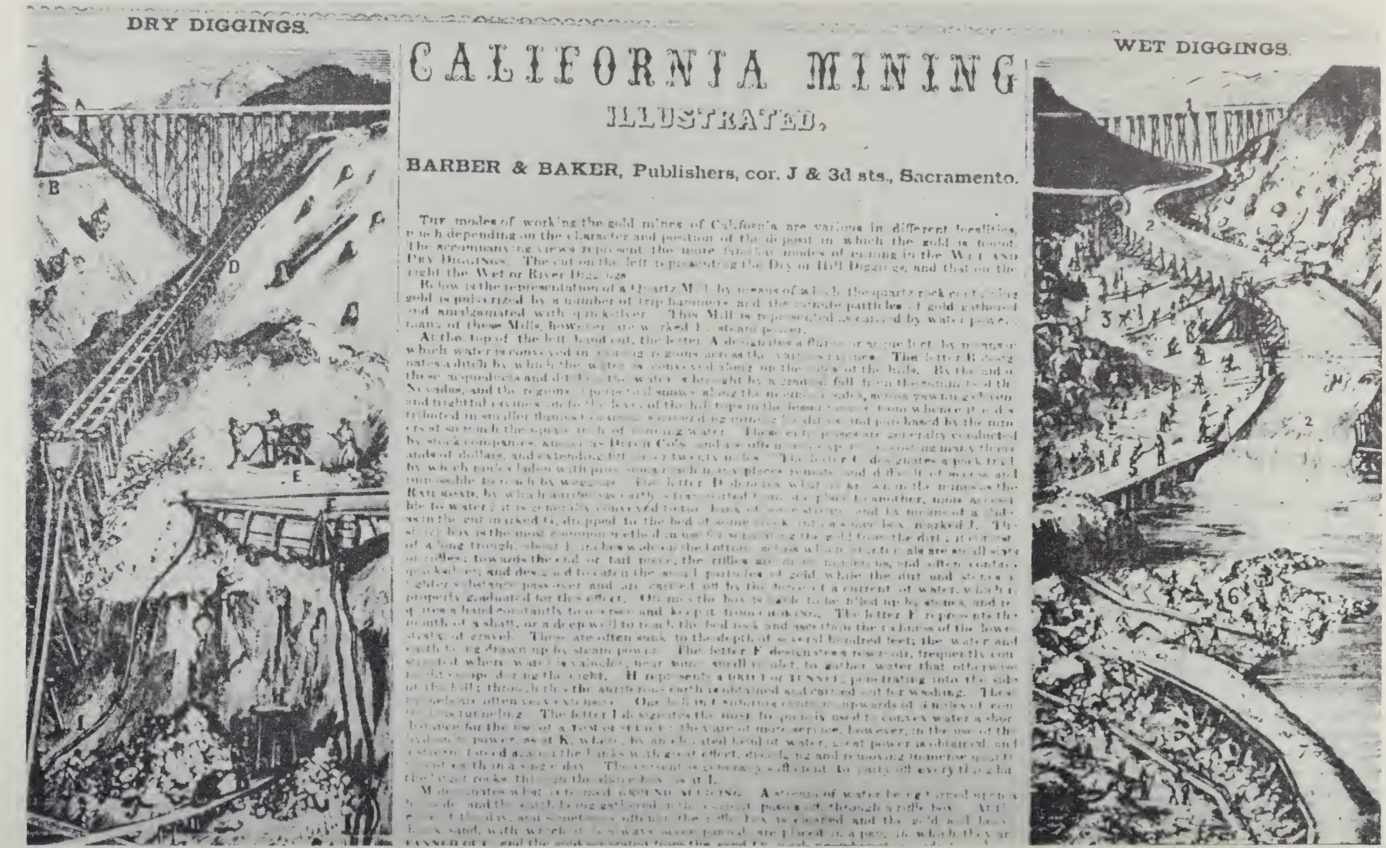
After the discovery of gold, by James W. Marshall, at Sutter's Mill on the South Fork of the American River, near Coloma, in the early Spring of 1848, altho' the forests and glens were almost untrodden, their stillness unbroken, except by wild animals, and Indians; the "Prospector," with his pick or shovel upon his shoulder, his pan in his hand, and his knife and trusty revolver in his belt around his waist, began to wander among the hills, and up the ravines and gulches "prospecting" for gold.

In 1849 and 1850 it was very common for small companies of men to start on a prospecting excursion, with several days' provisions, cooking utensils, blankets, tools, and fire-arms, at their backs; and with this small mule-load, climb the most rugged and difficult mountains; descend and cross the most rocky and dangerous canyons; endure fatigue and hardships; and brave privation and peril almost entirely unknown at the present time.

Sometimes it is true an animal might be taken for that purpose; but if his neck was not broken, he was almost invariably the cause of more anxiety and trouble than of comfort; as men would often have to travel over snow, into which an animal would sink; and cross an impetuous mountain stream upon a small pine, which, of course, no animal would ever attempt; and could he have been induced to enter the stream for the purpose of fording it, the force of the rushing water would have tripped him off his feet and dashed him to pieces upon the rocks; so the company's course had to be entirely changed, or the enterprise abandoned.

---

* This description of gold mining as it was carried on between 1848 and 1857 was published in *Hutchings' California Magazine*, Volume 2, for July (no. 1), September (no. 3), and October (no. 4), 1857.



CALIFORNIA MINING

ILLUSTRATED,

BARBER & BAKER, Publishers, cor. J & 3d sts., Sacramento.

The modes of working the gold mines of California are various in different localities, much depending on the character and position of the deposit in which the gold is found. The accompanying views represent the more familiar modes of mining in the Wet and Dry Diggings. The cut on the left representing the Dry or Hill Diggings, and that on the right the Wet or River Diggings.

Below is the representation of a Quartz Mill by means of which the quartz rock containing gold is pulverized by a number of trip hammers and the minute particles of gold gathered and amalgamated with quicksilver. This Mill is represented as carried by water power; many of these Mills, however, are worked by steam power.

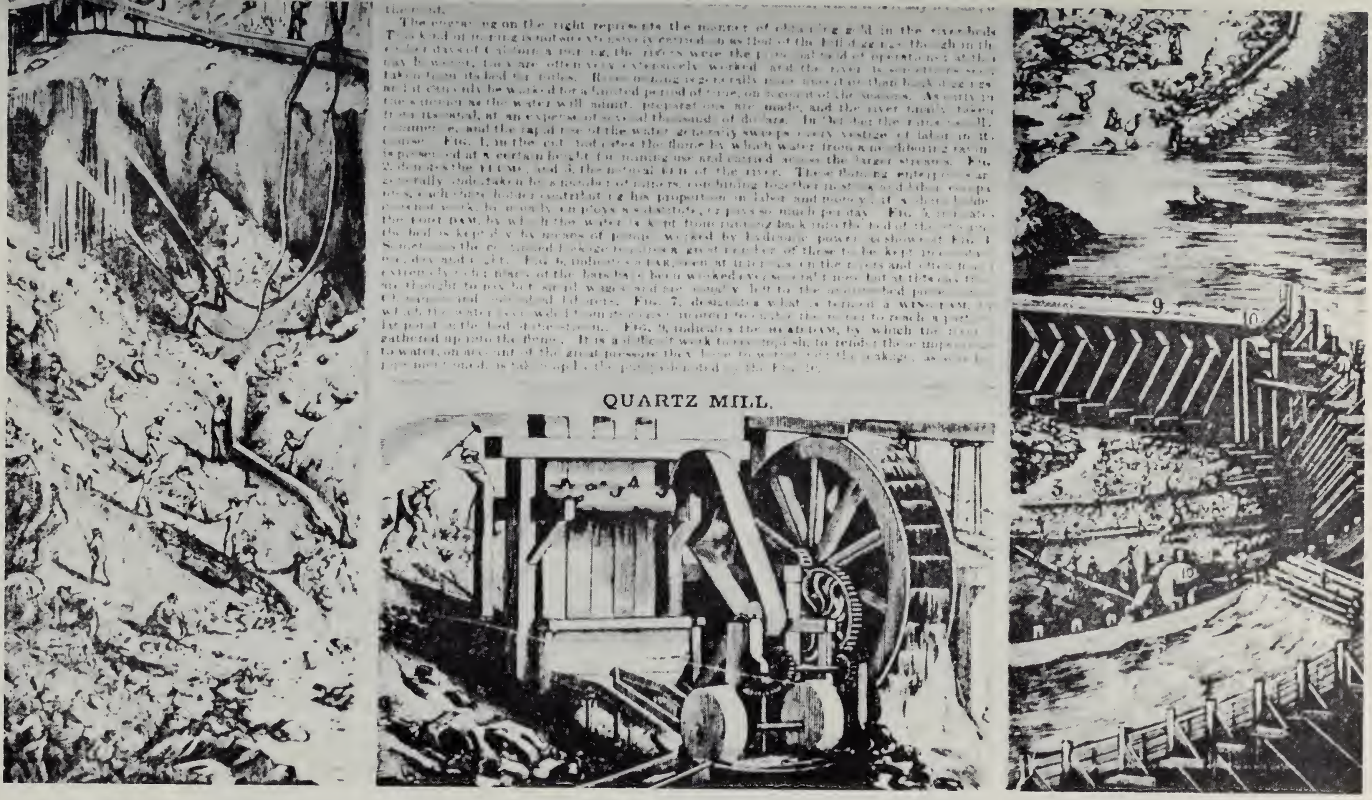


FIGURE 17. CALIFORNIA MINING ILLUSTRATED: Barber & Baker, Publishers, cor. J & 3d sts., Sacramento; entered according to Act of Congress, A.D. 1855, by BARBER & BAKER in the Clerk's office of the District Court, for the Northern District of California. Photo by courtesy of Society of California Pioneers, San Francisco.

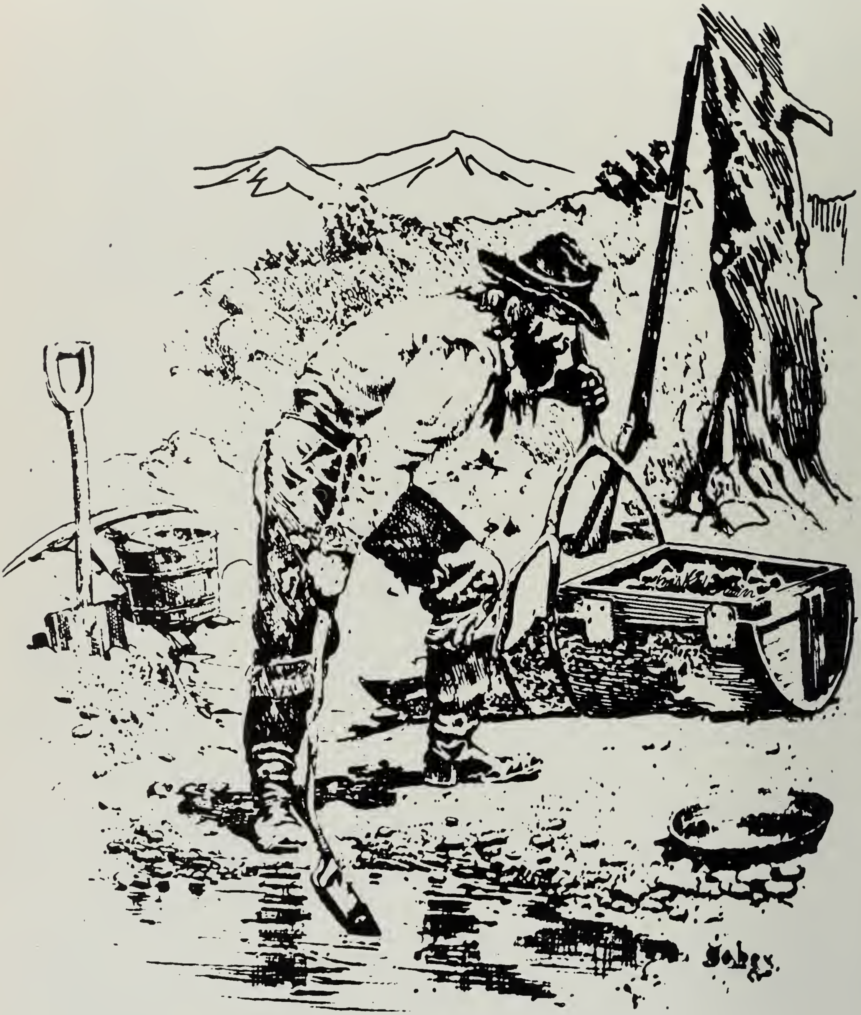


FIGURE 18. A PRIMITIVE OUTFIT (AFTER A SKETCH FROM LIFE IN 1850, BY J. W. AUDUBON, IN THE POSSESSION OF HIS DAUGHTER, MISS M. R. AUDUBON.) Photo by courtesy of Sutter's Fort Historical Museum, Sacramento.

At that period the precious metal was supposed to be found only in rivers, canyons, gulches, or ravines; and, as the latter were the readiest prospected, and the easiest worked and often paid very well; they offered the most tempting inducement to the prospectors; and consequently, were the first places sought after and tested by him.

Having arrived at a spot which looked inviting, and which he thought would "pay" down would go his pan and pick, or shovel and after removing some of the loose earth or stones which were lying on the top, he would commence making a small hole (generally about the size of his hat!) in the lowest part of the ravine, from whence a pan full of dirt would be taken, and washed; and, if found to be rich, a "claim" or "claims" would be immediately staked off, and a notice put up which generally read as follows:

"*We, the undersigned, claim fifteen feet square* (or other quantity mentioned) *commencing at this stake, and running up this ravine to the oak tree with a notch in it.*

"(Signed)

PETER SNIGGINS
JERAMIAH TURTLE."

If, however, a good prospect was not obtained in the first pan full of auriferous dirt, the second was seldom attempted by the prospector of 1848.

Before leaving him, let us see how his pan full of dirt is washed—as the process of "panning out" is precisely the same now as it was then, and is an indispensable accompaniment to every method of gold mining.

Having placed his pan by the edge of a pool or stream, he takes hold of the sides with both hands, and squatting down lowers it into the water, then, with a kind of oscillating and slightly rotary motion, he moves it about beneath the surface for a few moments, then, after drawing it to the edge of the pool, he throws out the largest of the stones, and assists to dissolve the dirt by rubbing it between his hands; the washing has been repeated; and, while the muddy water and sand are floated out of the pan into the pool, the gold, if there is any, settles gradually to the bottom of the pan and is there saved.

If a little only of very fine gold was found, it was called in miner's phraseology "finding color," and if from ten to twenty-five cents were found to the pan, it was called "a good prospect." Now, however, with improved modes of mining, and less extravagant expectations, from *one* to *three* cents is pronounced "good pay dirt."

The Mexicans and Chilians use almost exclusively the *batea,* or broad wooden bowl . . . instead of the pan.

Next to the *pan* and bowl as implements for the more speedy separation of gold from the earth, the *cradle* or *rocker* holds an important place; from the fact that it was the first appliance, superior to the pan used with effect in all parts of the mines. Its size and weight rendering it portable, it was easily transferred from place to place, and even now is much in use as a prospecting implement upon a scale more extended than can well be executed with the pan.

Our description of the cradle or rocker is this: An oblong box from three to three and a half feet in length, 18 to 22 inches in width, and about nine inches in depth at the upper end, with a bar across the middle; one end of the box is left open or has no end board. There is no cover to the box or cradles; but a separate box, sieve, or hopper, is made to fit into and occupy the half of the cradle furthest from the open or lower end; this hopper is about four inches in depth; the bottom is of sheet iron, perforated with holes about three-eights or half an inch in diameter, and one and a half inches apart.

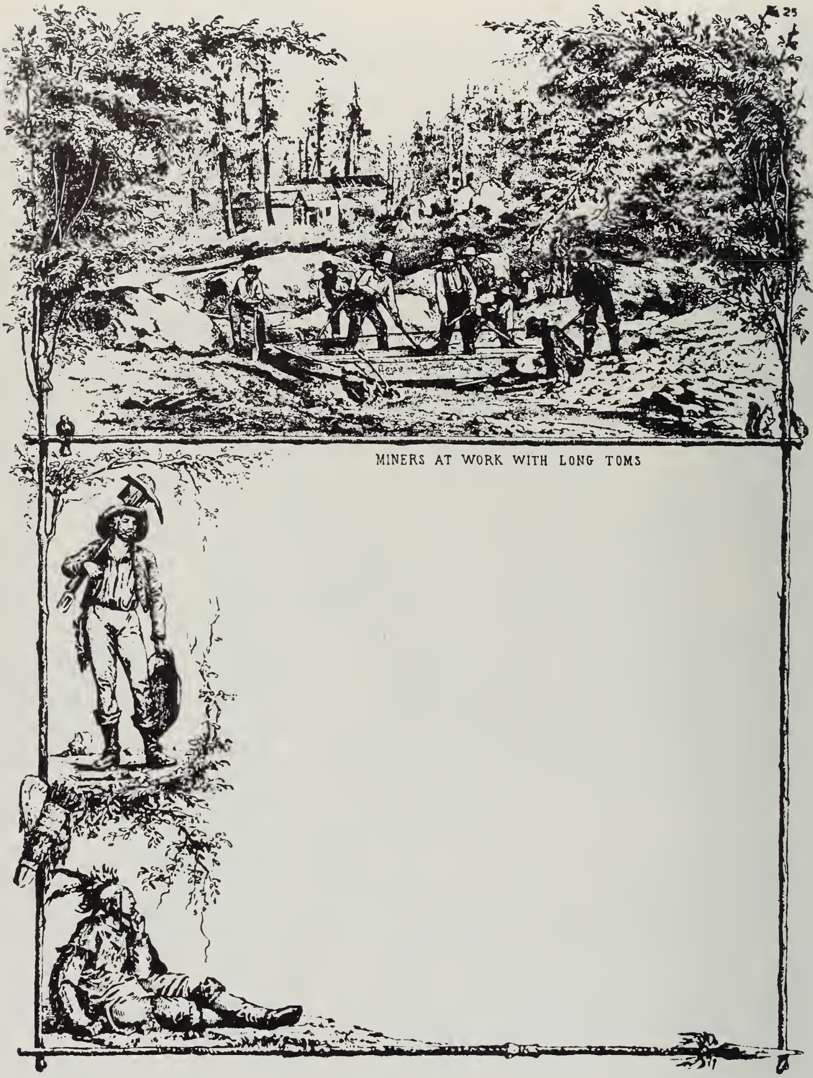

25
MINERS AT WORK WITH LONG TOMS

FIGURE 19. MINERS AT WORK WITH LONG TOMS. Photo after letterhead, by courtesy of California Historical Society, San Francisco. A copy at Sutter's Fort Historical Museum carries the following handwritten notation: "California Miners, and 'Long Toms', 1850.—I bought this sketch in the mountains, and sent it home in a letter to Mother, in 1850. It is from a Photograph of a group of Miners on Weber Creek, a tributary to the South Fork of the American River, California, where I mined three weary years,—Yet it is a beautiful region, when seen from the Lofty Spurs of the Sierra,—But wild as the primal Chaos, in these deep ravines, and rocky gorges, which in winter are Cataracts."

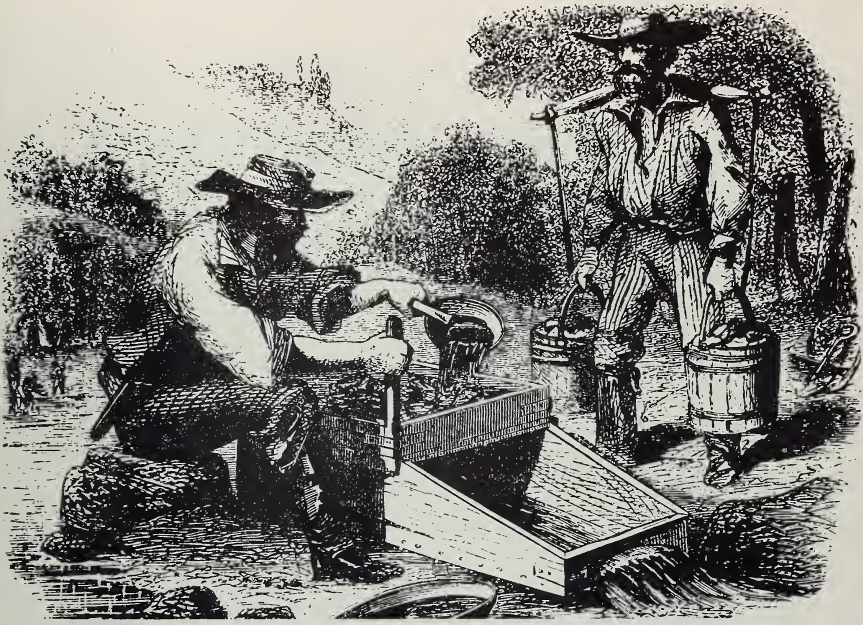


FIGURE 20. CRADLE ROCKING, ON THE STANISLAUS. Published in *California, A Book for Travellers and Settlers,* by Charles Nordhoff, 1873, as CRADLE ROCKING. Photo by courtesy of California Section, California State Library, Sacramento.

Under the hopper and sloping downward toward the upper end of the cradle, is the *slide* or *apron*. This apron being somewhat hollow or concave on its upper side, and covered with canvass, retains much of the fine gold that falls upon it.

Rockers are attached to the outer side of the hole, quite similar to those of the child's cradle; near the middle an upright handle is attached, by which motion is given to it.

The hopper being nearly filled with auriferous earth, the operator being seated by its side, for rocking the cradle with one hand, he dips and pours on water with the other, from an adjacent pool or rivulet using a half gallon tin dipper for the purpose.

The water dissolving the earth, falls through the sieve on the sloping apron, which conveys it to the upper end of the bottom of the cradle. Of this bottom, about the center is a "riffle-bar" placed crosswise, and one a little deeper at the lower end; and while the latter sand and dirt passes over them with the water, the gold, by its greater weight, is retained by them, and thus kept from passing out of the lower end.

The coarse stones and gravel remaining in the hopper after the water runs clear are then thrown out, the hopper replaced and refilled, and the process repeated. As often as is necessary, the apron, riffle-bars, and bottom are cleaned of the sand and gold that has concentrated upon them; the larger portion of the fine gold, being generally found upon the canvass of the apron.

The cradle, though still extensively used by the Chinese throughout the mines, has given way among Americans, and the more enterprising class of miners, to more summary methods for separating the gold from the pay-dirt; its use being superseded by far more efficient implements; and among them, as next in importance to the cradle, was introduced the "Long-Tom."

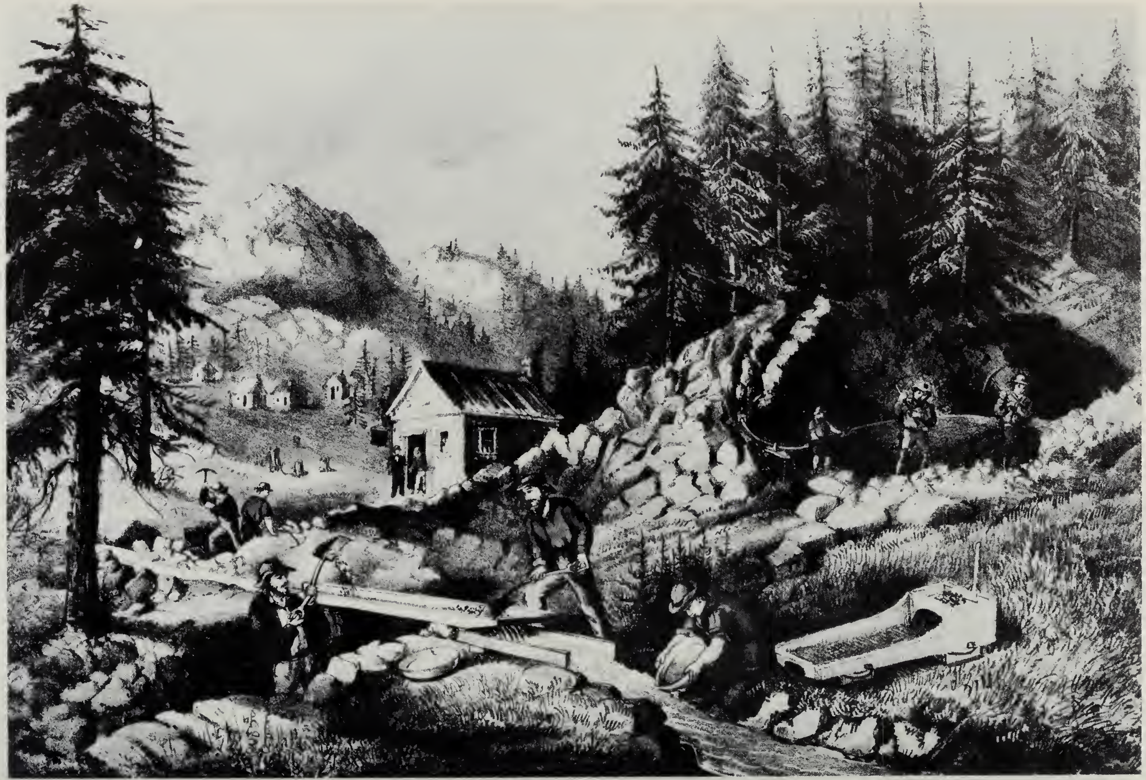


FIGURE 21. GOLD MINING IN CALIFORNIA: Published by Currier & Ives, 125 Nassau St., New York; entered according to act of Congress in the year 1871 by Currier & Ives in the Office of the Librarian of Congress at Washington. Photo by courtesy of California Historical Society, San Francisco.

The Long Tom

It was not long after the pan and cradle were in general use, and it became apparent that some more expeditious mode was required for washing the gold from large quantities of earth. Men were not satisfied with the slow, one man system, the use of pan or cradle; but something must be done, some invention made of an implement by the use of which the united efforts of individuals, as companies, could be made available and profitable.

To supply this want, the wits and ingenuity of the earlier miners soon brought out the "long tom," exceedingly primitive in its first inception and form it is true, but proving so effective in its operations, it was soon greatly improved upon, and at length became the indispensable implement in the hands of companies of from three to five men in prosecuting their gold washing operations.

From the primitive toms, which were but troughs hollowed out from the half trunks of pine trees, they soon assumed the proportions and shape of the neatly constructed tom of sawed lumber and sheet iron of the present day.

The tom varies much in size, depending on the number of men intending to use it. It is an oblong box or trough about 12 feet in length, open at the top and usually at both ends; but always at the lower end. It is about eight inches in depth, and at the upper end from one foot to two feet in width; but increasing to nearly double that width at the middle, from thence its sides are parallel to the lower end. The bottom of this broad portion for a distance of from three to six feet from the end, is made of strong, perforated sheet iron, in every respect similar to the sieve or hopper of the cradle, but of much heavier iron. The tom is not straight upon its bottom the whole length; but the sheet iron portion is turned upward as it approaches the lower end, so that the depth of the tom is diminished at the end to less than three inches. The object of this is that the water may all pass through the sieve or tom-iron without running over the top.

Under this perforated iron portion is placed a riffle box, similar in principle to the bottom of a cradle; but larger, and alike with the tom, always to remain stationary or immovable while in use.

The tom is now placed in a proper position, having reference to the dirt to be washed, generally as near the ground as possible to admit of the "tailings" passing off freely. The riffle box is first fixed in proper position, then the iron-bottomed portion of the tom placed over it, with its open or narrow end several inches the highest. Water is now let on, either in open troughs of wood, or through canvass hose, which by its force, carries the dirt when put in, down the tom; and while two or more men are employed shoveling the dirt into the tom at the upper end one man at the side of the lower end, with hoe or shovel in hand, receives the dirt as brought down by the water; and after being violently stirred and moved about upon the perforated iron bottom until all has passed through it that will, the residue of stones and coarse gravel is thrown out by the shovel.

The manner of saving the gold by the riffle box, is precisely the same in principle as that of the cradle, with this advantage over it; that the falling of streams of water through the tom iron serve to keep the sand upon the bottom of the riffle box stirred up and loose, permitting the gold the more easily to reach the bottom, where it is retained by the riffle bars; for the lighter matter, sand and pebbles, pass off with the water and is called "tailings."

Sometimes 30 or 50 feet or more of sluice boxes are attached to the tom at the upper end, and the dirt is shoveled in along the whole length, to be

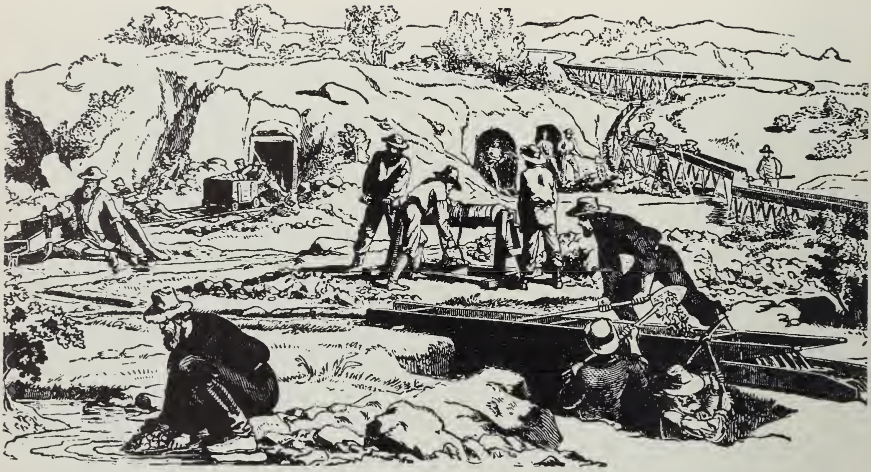


FIGURE 22. HOW THE CALIFORNIA MINES ARE WORKED: Anthony & Baker, Sc; published at the Wide West Office, 184 Clay St., San Francisco. Photo after *A Pictorial History of California*, by Owen C. Coy, by courtesy of University of California Extension Division, Berkeley, and Wells Fargo Bank & Union Trust Co., San Francisco.

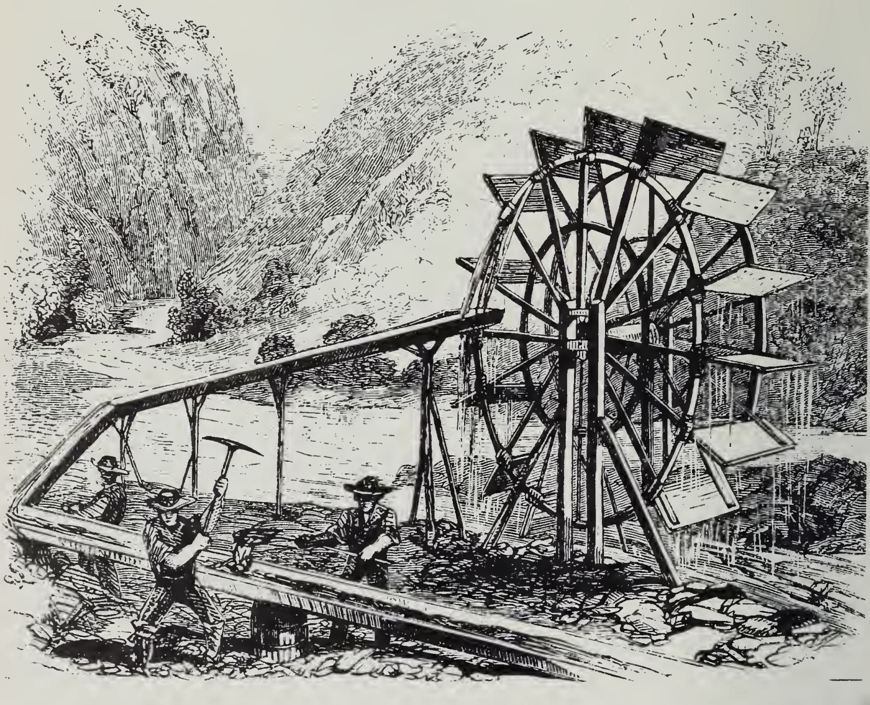


FIGURE 23. FLUTTER WHEEL ON THE TUOLUMNE. Published in *California, A Book for Travellers and Settlers*, by Charles Nordhoff, 1873. Photo after *A Pictorial History of California*, by Owen C. Coy, by courtesy of University of California Extension Division, Berkeley, and Wells Fargo Bank & Union Trust Co., San Francisco.

carried down to the tom by the force of the water, there to receive its final stirring up.

Toms are particularly adapted to nearly level grounds, or where there is not sufficient fall to admit of the still more efficient mode of gold washing with sluices.

Sluicing

This is a mode of mining particularly adapted to those localities where it becomes desirable to wash large quantities of dirt, and where the descent is sufficient to operate advantageously.

To get at a proper understanding of this method of mining, seems to require a description of the "sluice box." This is merely an open trough usually made of three-inch boards—a bottom, and two sides; 12 or 14 feet in length, and from 12 inches to 40 in width, and sawed purposely for this use, two inches wider at one end than at the other. The sides of these troughs are secured from spreading by cleats nailed across the top; and from splitting at the bottom, by similar cleats on the under side.

The continuous line of these troughs or "sluice boxes," the smaller and lower end of each, inserted for three or four inches into the larger end of the next one below, from the "sluice," and being placed upon the ground or other supports, with the proper descent; the dirt, by whatever mode is adopted to remove it thereto, and into the sluice, either by shoveling, or the power of the hydraulic as hereafter described, is, by the force of a larger body of water than is usually used in tomming, conveyed through a continuous line of from fifty to several hundred feet in length, and when the descent is sufficient, the whole mass of dirt, from the finest particles, to stones and boulders of four or five inches in diameter, go rattling down by their own gravity and the force of the water, the entire length of the sluice.

Where the descent is not quite sufficient for this, forks and shovels are used along the sluices to loosen up and finally to throw out such of the larger stones and rocks as the water cannot force through them; as shown in the engraving [fig. 24].

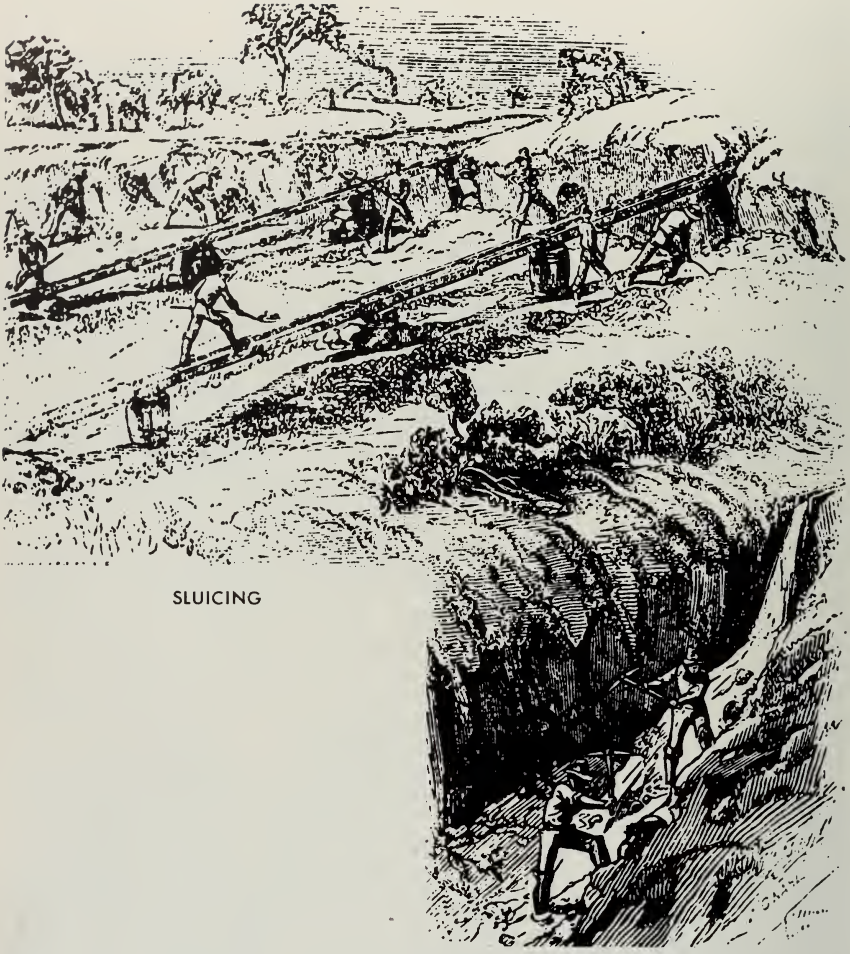
There are different appliances attached to the bottoms of these sluices, inside, for the purpose of saving or catching the gold in its passage down the sluice, such as riffles of a great variety of pattern, and false bottoms, perforated or split in pieces, the interstices of which are admirably adapted to the saving of mined gold.

These sluices are sometimes "run," as it is termed, for many days together before "cleaning up;" when this is done the false bottoms of the riffles are removed, the sluices "washed down," and the gold secured by being carefully swept down the whole length of the sluice into a pan, to be more thoroughly cleaned out by "panning out."

This is doubtless of all others the most expeditious mode of mining or separating the gold from the dirt that has yet been discovered, and where it can be adopted is doubtless the best.

Ground Sluicing

Among the more important operations connected with gold mining upon an extensive scale, is "ground sluicing." Localities are often found in which the largest portion of the gold lies upon, or near the "bed rock;" above which may rest a depth of earth of many feet, containing no gold, or so small a quantity compared with the mass of dirt, that it would not pay either to wash in sluices or for the expense of removal in any other way than by ground sluicing.



SLUICING

GROUND-SLUICING

FIGURE 24. SLUICING AND GROUND SLUICING: C. Nahl; W. C. Butler, Sc., S. F. Photo after Hutchings' California Magazine, 1857, by courtesy of Sutter's Fort Historical Museum, Sacramento.

The principle of the operation is this; a bank of earth is selected which is desired to reduce or wash away, down to the pay dirt; a stream of water is conducted thereto, at so high a level as to command it; a small ditch is then cut along the portion to be ground sluiced, the water turned on, and then any number of hands with picks and shovels either upon the edges of the ditch or by getting directly into the stream of water, pick away and work down the banks and bottom, to be dissolved and carried away by the water, while the gold that may be contained in it, settles down without being conveyed or lost, to be finally saved by being passed through the ordinary sluice.

When the process is solely for the purpose of removing the top strata of earth in which no gold or pay dirt is found, down to that which will pay, it is called "stripping," by ground sluicing. Often however when no pay is expected from the stripping process, the miner is unexpectedly cheered by finding in the top dirt more gold than sufficient to pay all the expenses of the operation.

Sinking a Shaft

The mining region of California in its physical conformation is made up to a great extent of immense ridges and hills, with gulches and ravines intervening, and all underlaid by what is usually termed "bed rock." In very many places this bed rock assumes upon its surface the form of basins deep beneath the great earth ridges, and these basins are frequently found to be exceedingly rich in their gold deposits.

To reach the bed rock in these positions, two methods are adopted; "sinking shafts" and "running tunnels."

To "sink a shaft"—a shaft being a perpendicular opening in the earth usually from four to six feet in diameter—the same means and appliances are ordinarily used as in sinking a deep well; which in fact it so much resembles, except that it is seldom walled up as wells are, nor is water desired in them; but which unluckily too often occurs.

Sometimes a "streak" or strata of pay dirt is reached, before arriving at the bed rock, and is termed a "lead." When the lead is followed horizontally to the right or left from the shaft, it is termed "drifting;" and when the bed rock is reached, if operations are continued they are all done by drifting.

The pay dirt is raised to the surface by the same means that are used in sinking the shaft, the principle of which is, the windlass and bucket, or tub. Sinking shafts is often performed, solely with the view of prospecting, in the cheapest and most expeditious manner, the bed rock, before proceeding to the greater expense, but more efficient mode, of working these deep hill claims by "tunneling." But this is not always the case; for shafts are sometimes sunk upon flats, to a great depth, and the entire process of mining out all the lead, conducted through the shaft; in aid of which, steam engines are often employed.

Tunneling

Tunnels are usually commenced upon hillsides, or near the bottom of gulches and ravines and are run in nearly horizontal. Commencing at the surface upon the proper level, or what is supposed will prove to be the proper level, when the basin of the hill or pay dirt is reached, an open cut is first made into the hill, until a sufficient depth is attained to enable the tunnel to be commenced, with enough of earth or rock overhead to sustain itself in the form of an arch, or if of earth only and inclined to cave in, then to be supported by "timbering" at a height scarcely sufficient to clear a tall man's head when standing upright.

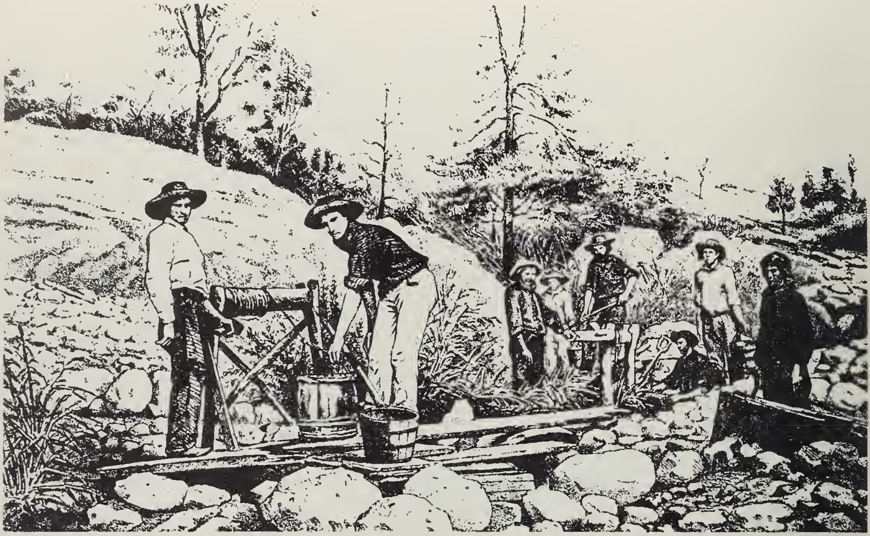


FIGURE 25. THE MINERS: Lith. & publ. by Quirot & Co., corner California & Montgomery Streets, San Francisco. Photo after MINERS AT WORK, in *A Pictorial History of California,* by Owen C. Coy, by courtesy of University of California Extension Division, Berkeley, and Wells Fargo Bank & Union Trust Co., San Francisco.

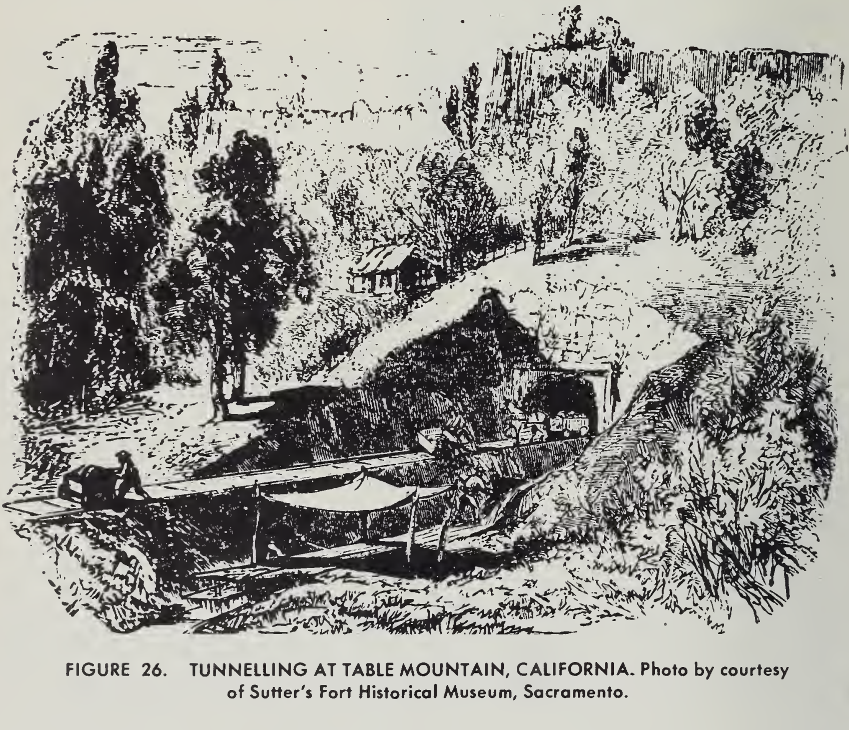


FIGURE 26. TUNNELLING AT TABLE MOUNTAIN, CALIFORNIA. Photo by courtesy of Sutter's Fort Historical Museum, Sacramento.

The tunnel is now commenced, and usually from five to seven feet in width. When only earth and detached stones or boulders are met with, it often becomes necessary to "timber up," as the tunnel progresses; which is done by setting strong posts about three feet apart on each side, and opposite to each other; and these supporting a cross timber above, and on these one or more plank are laid which support the roof; sometimes the sides are necessarily planked also and on these one or more planks are laid.

In very many instances the tunnel is "driven" by picking and blasting through solid bed-rock many hundred feet in length, requiring a great expenditure of time, labor, money, and perserverance. To convey from the tunnel, the excavated portions of rock, stones, and earth, the wheelbarrow was formerly in general use, and is even now in many places; but with the more systematic, a narrow rail-road is constructed as the work progresses, on which is run a suitable car, the bottom of the tunnel having the necessary grade to enable a loaded car to be propelled outwardly easily by man power.

When the pay dirt is reached, a division is made of the excavated portion on being brought out, into that which is, and is not, pay dirt, and as often as expedient when water is procurable, it is washed by sluicing in the usual manner.

Fluming

Only those who are familiar with the physical formation of the mountain and gold region of California, have anything like an adequate idea of the vast amount of labor expended, in the construction of the artificial water-courses that supply our mining canals and ditches with water from the mountain streams.

To hear of the construction of a hundred miles of mining ditch, conveys but a feeble conception of the magnitude of the enterprise, or the difficulties to be overcome. The mountain country from which the supply of water is obtained, does not consist of slope upon slope, or of successive tables of comparatively level land, and rising one above another; but from the foot hills, the mountains rise to the height of from seven to nine thousand feet in one uninterrupted succession of immense ridges, lying in every conceivable direction and position, with intervening gorges or canyons of corresponding depth; and by this we mean, a very great depth; many of the mountain streams occupying and rushing down canyons, whose sides are almost perpendicular walls of rock, and often three thousand feet or more in height, and along which the pedestrian can only make his way for a hundred yards together, by taking to the bed of the stream.

It is from such canyons, that the water is mostly obtained for the supply of our mining canals and ditches; and it is not unusual that from three to ten miles of wooden flume is required at the upper end, before the water can be brought out of the canyon sufficiently high to o'ertop or command the ridges and foot hills of the lower country, in which the mines and placers are principally found.

To lift as it were, the waters from these deep canyons, or rather to convey them at a fall of from five to twenty feet to the mile, out of them, often requires many miles of flume constructed entirely of wood, because the steep sides have not, in many places, a single inch of earth in which to excavate a ditch; and even the rocky sides often so high and steep as to require the flume to be constructed upon tresseled work, a hundred or more feet in height; and even in some instances actually suspended by iron work, upon the smooth face of almost overhanging rock and precipices; the workmen are let down and suspended by ropes from above, while prosecuting their arduous labors.

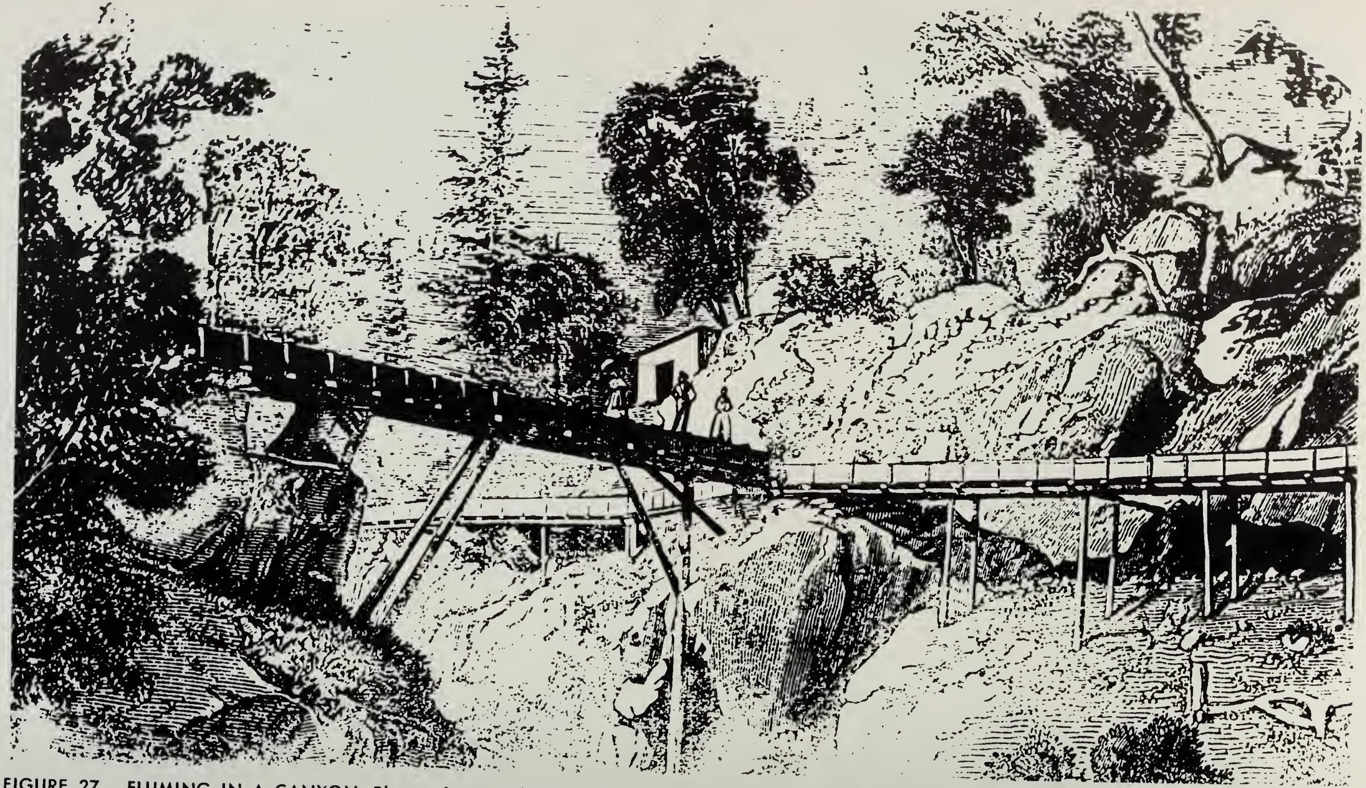


FIGURE 27. FLUMING IN A CANYON. Photo after Hutchings' California Magazine, 1857, by courtesy of Sutter's Fort Historical Museum, Sacramento.

Then again, the flume is made to span a vast gorge sometimes, and in places supported by timber work from beneath; at others, by suspension from the sides; and in its tortuous course, running up and crossing adjacent gorges, perhaps to take in the waters of some small tributary, and then again heading for and coursing along the great main canyon, leaping as it were, from point to point of jutting crag and cliff, till at last it reaches the more earthy side or summit of the ridge, there to be at once used for gold washing, or milling purposes, or conveyed by ditches in countless ramifications to the lower mining world; and these enterprises constitute the great fulcrum of our mining prosperity.

The Hydraulic Method of Working

By far the most efficient system of mining yet known, for hill digging, is the hydraulic; for the discovery of which California is indebted to Mr. Edward E. Matteson,† formerly of Sterling, Windham County, Connecticut. . . .

Mr. M. first commenced the use of this method at American Hill, Nevada, in February, 1852,† and such was the success attending its operation that others around him immediately began to adopt it; and it is now in general use throughout the mining districts of the State.

Water being conveyed . . . by canals and ditches, around and among the hills and mountain sides where mining is carried on, it is thence distributed from the main canal by smaller ditches to the mining claims requiring it.

Here it is run from the small ditch into a trough fixed above tressel work, which is often technically termed the "Hydraulic Telegraph"; or, run in heavy duck hose upon the ground, to the edge of the claim, thence over the edge and down the almost perpendicular bank to the bed rock, or bottom of the claim, where it lies coiled about on the rock and dirt like a huge serpent. As the upper end of the hose is much larger than the lower end, the water running in, keeps it full to the very top; and the weight of this water, escaping through a pipe attached to the lower end of the hose, in a similar manner to that of a fire engine, plays upon the bank with great force and effect, washing it rapidly away.

There are sometimes stratas of gravelly cement in the bank which are exceedingly hard and difficult to wash away, even with the immense force given by the weight of from 50 to 220 feet of fall, which the water contained in the hose receives from above.

The most efficient manner of washing down these banks is by undermining them near the bed rock, when large masses—frequently many tons in weight—"cave down" and not only break themselves to pieces by the fall, but unfortunately often bury the too venturesome miner beneath them. It is from this kind of mining so many accidents have occurred; and when we read in the newspapers of the day that Mr. so and so was badly injured—or killed—by the "caving of a bank," we may know it is generally in such places.

If the reader will please refer to the engraving [fig. 28] he will see a stream of water running over the bank, which is often required effectually to cleanse and remove the large quantities of earth and rocks washed down by

---

† According to C. A. Logan, "Edward E. Mattison, working at American Hill, just north of Nevada City in 1853, is credited with first making use of water under pressure to undermine and wash gravel into sluice boxes. . . . The method was introduced at Yankee Jims, Placer County, in 1853, by Colonel William McClure, who had visited Mattison's mine that year." (See *History of Mining and Milling Methods in California*, in California Div. Mines Bull. 141, p. 31, 1948.)

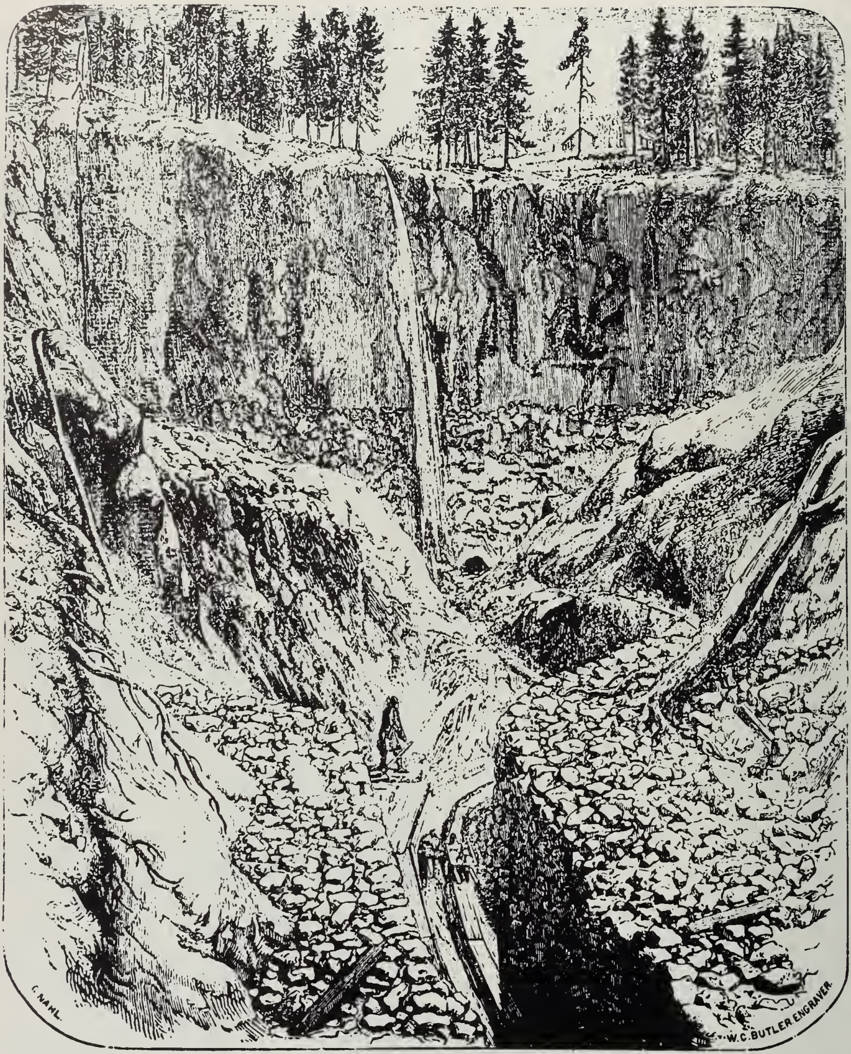


FIGURE 28. HYDRAULIC METHOD OF MINING: C. Nahl; W. C. Butler, engraver. Published in Hutchings' California Magazine, 1857. Photo from letterhead by courtesy of California Historical Society, San Francisco.

the pipe, and convey them to the sluice, down which they pass, and in which the gold is principally saved, although large amounts of the golden dust fly among the earth and stones, but a few feet from whence they were washed.

After "cleaning up" the rock and "washing down" the sluice, the precious contents are swept into a pan where they are carefully panned out. After the day's work is done, the miner repairs to his cabin to build his fire, cook and eat his supper, dry his dust, and blow out the black sand.

Sometimes when a man has been covered up by the bank falling upon him, not only the stream generally used in the claim, but often the entire contents of the ditch are thus turned on, and with the assistance of every miner who knows of the accident, it is used for sluicing him out, and which is by far the speediest and best method for his deliverance.

One becomes surprised when looking at the bold defiant strength of a miner's will and purpose, and the risk he so often runs, that comparatively so few accidents of this kind occur. By care, however, this branch of mining can be conducted with the same safety as any other.

The "hydraulic process" removes and washes immense masses of earth that would otherwise be useless and its working unprofitable, thus making it not only one of the most useful and effectual, but almost indispensable method of mining for gold in California.

River Mining

At this season of the year, when every energy of the enterprising river miner is concentrated upon the great undertaking of his arduous work, it may not be amiss to describe the manner in which the plannings of his mind, perhaps for months, or even years, are carried out.

When it becomes desirable to chain the mountain torrent, which is heedlessly rushing past, and turning it out of its natural channel, that the glittering gold, lying in the river's bed, may be transferred from thence to the buckskin purse of the miner; he talks the matter over with some confidential and trustworthy and hard-working companions, when they mutually agree that "there is gold there—sure," if they can only get it.

The ways and means are accordingly devised; sometimes for making up a company of eight, or ten, or twenty, or any other desirable number; and as the cost will be about so much, each member of the company has to contribute his share of the amount agreed upon, as the work progresses. Should it cost less or more—generally it is the latter—the proportion is diminished, or increased by assessments according to the number of shares. At other times, a number of men who live together on the same bar, and who, being well acquainted with each other, and tolerably well informed of what the other possesses, will raise whatever timber or tools may be required, from among themselves, and "get along as well as they can, for the balance"—which often is but very indifferently—and go to work with a will to accomplish their object.

To do this, sometimes, a race has to be dug; and others, a flume has to be built, requiring to be of sufficient capacity to take in the whole amount of water running in the river. This being done, a dam has to be constructed across the river, that shall be water-tight, or nearly so. To build this dam, very often requires that men work in the water, which is generally very cold, for, as it comes from the melting snows, it cannot be expected to be very warm; at least, before the river is very low, and men seldom wait for that—they therefore enter the river; and by rolling up large boulders into a line for building a wall, they turn the water from the one side towards the flume on the other, and when one wall is thus rudely but substantially constructed, another is built

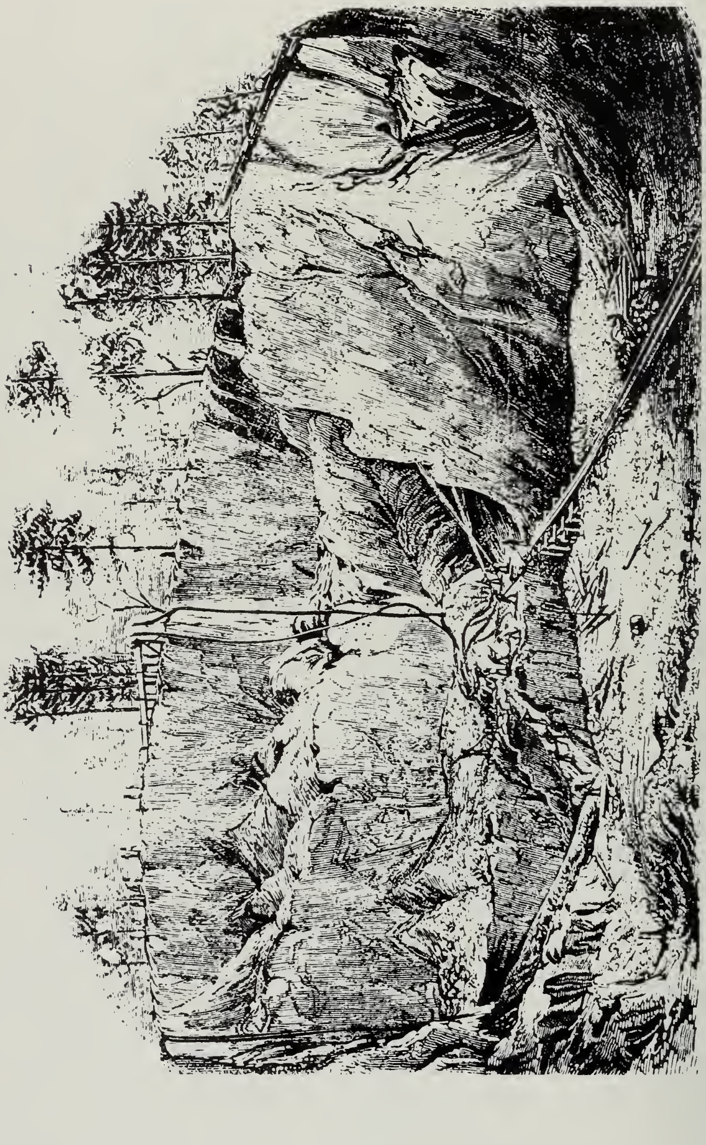


FIGURE 29. RICH CLAIM, IOWA HILL: Barber & Baker, Publishers. Photo from letterhead, by courtesy of California Historical Society, San Francisco.

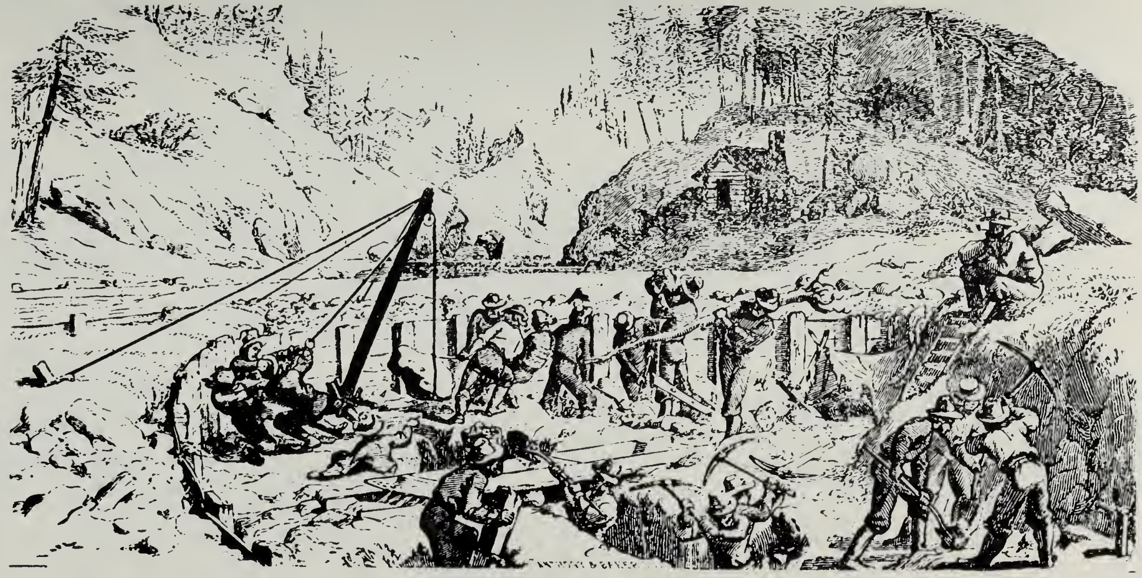


FIGURE 30. MEN ENGAGED IN WORKING OUT THE RIVER'S BED AFTER TURNING THE STREAM INTO THE FLUME: Anthony & Baker, Sc.; published in Hutchings' California Magazine, 1857. Photo from letterhead RIVER MINING: Published at the Wide West Office, 184 Clay Street, San Francisco; by courtesy of California Historical Society, San Francisco.

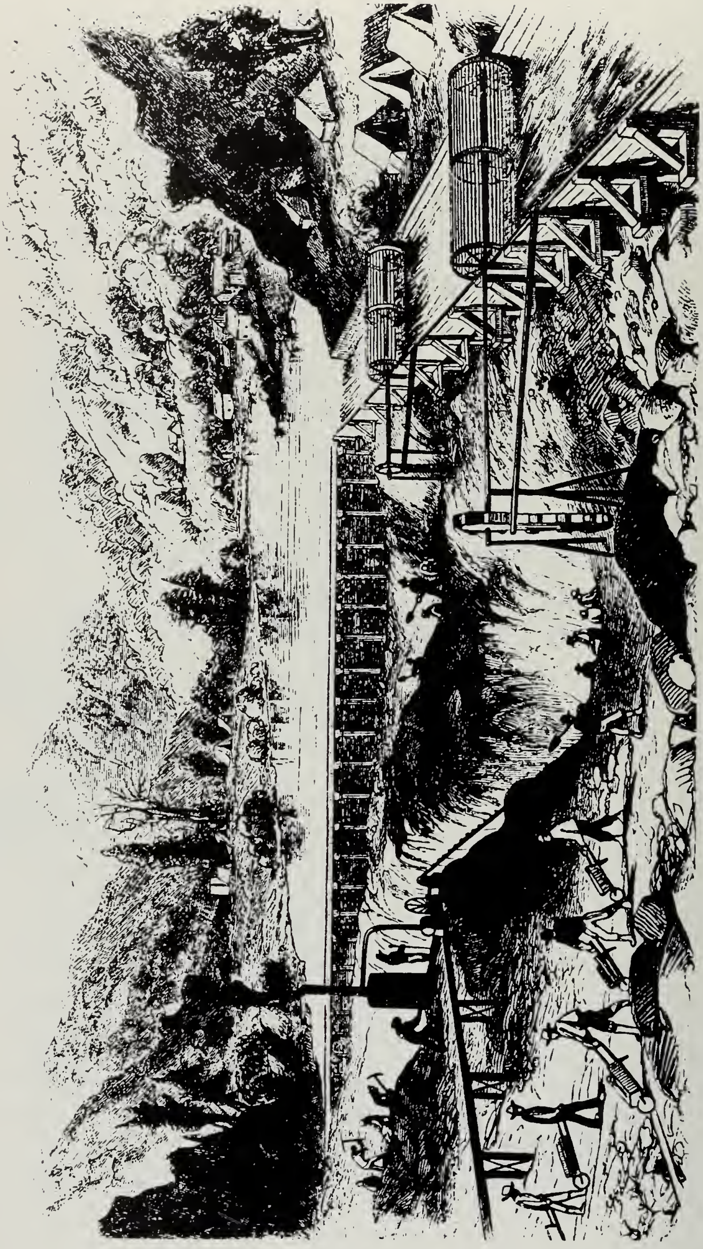


FIGURE 31. RIVER OPERATIONS AT MURDERER'S BAR. Published in *California, A Book for Travellers and Settlers,* by Charles Nordhoff, 1873, as TURNING A RIVER. Photo after *A Pictorial History of California,* by Owen C. Coy, by courtesy of University of California Extension Division, Berkeley, and Wells Fargo Bank & Union Trust Co., San Francisco.

behind it; when all the light floating sand is cleaned out, that it may not be in the way of making the space water-tight between the walls; the clayey soil is then filled in and well tramped, until the dam is tight; and the water is running through the race or flume. Sometimes a tree or log is felled across the stream, (if one can be found long enough to reach, and in the right place,) when slabs or split timbers are put in, in an inclined position, and either nailed or pinned to the log, when the whole space in front is filled up with clayey soil and fine boughs of trees until it is made water-tight.

The river now being turned into the race, wheels are erected across it; and pumps are attached by which the water still remaining in the river's bed is pumped out. Now river mining is commenced in real earnest; men begin to remove boulders, wheel out rocks, fix toms, or sluices, and take out the precious metal—if there is any. (The writer has seen as high as five thousand two hundred and twenty-seven dollars, taken out from behind a boulder, in a single pan of dirt.)

Should the fall rains be later before commencing, every opportunity is given to work out the river claims to advantage—or at least to test them sufficiently either to work or abandon them. If on the contrary—as frequently occurs—the rains should come early, the whole work of the summer's labor and expense are swept away before a dollar can be taken out.

Quartz Mining in California

Under the guidance of Mr. Daniels, of the far-famed Allison Ranch Lead, we descended their shaft—but not before the workmen had offered and we had accepted the loan of an India rubber suit of clothing—and on reaching the bottom of it we found a considerable stream of water running in the centre of the railway, constructed along the tunnel to the shaft. This water was removed by a pump in one corner of the shaft, working by steam power, both day and night.

On, on we went, trying to keep a sure footing on the rail track, inasmuch as water-tight boots even then became a very necessary accompaniment to the India-rubber clothing. Drip, drip fell the water, not singly, but in clusters of drops and small streams so that when we arrived at the drift where the men were at work, we had a sufficient supply of water for drinking purposes (!) in the pockets of our coat, the miners who were removing the quartz from the ledge, looked more like half-drowned sea-lions, than men. We did not make ourselves inquisitive enough to ask the amount of wages they received, but we came to the conclusion that they must certainly earn whatever they obtained. Stooping, or rather half lying down upon the wet rock, among fragments of quartz and props of wood, and streams of water; with pick in hand, and by a dim but waterproof lantern, giving out a very dim and watery light, just about bright enough, or rather dim enough, and watery enough, as Milton expresses it, "to make darkness visible," a man was at work, picking down the rock—the gold-bearing rock—and which, although very rich, was very rotten, and consequently not only paid well, but was easily quarried, and easily crushed; and although this rock was paying not less than three hundred and fifty dollars per ton, we could not see the first speck of gold in it, after a diligent search for that purpose.

At the bottom of the drift another man was employed to shovel the quartz into a tub standing on a railway car, and push it to the shaft, where it was drawn up and taken to the mill.

* * * * * * *

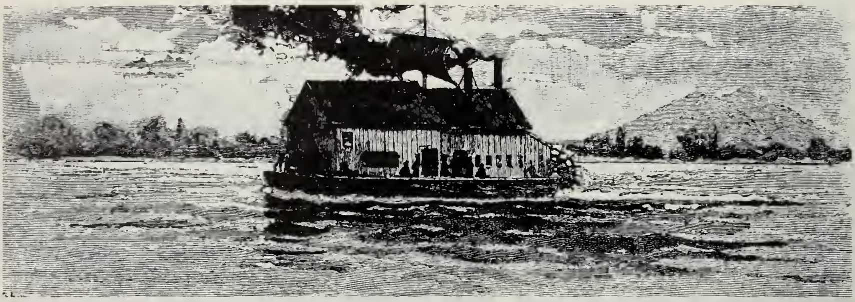


FIGURE 32. OLD STEAM DREDGER ASCENDING SACRAMENTO RIVER IN 1849. Photo after *Cape Horn and Cooperative Mining in '49,* by W. B. Farwell, in Century Illustrated Monthly Magazine, 1891, by courtesy of California Section, California State Library, Sacramento.

We had the satisfaction of descending the Osborne Hill lead, under the guidance of Mr. Crossett, and, after bumping the head against the rocky roof above, and holding on by our feet to the wet and slippery roof of rock below on which we were descending, at an angle of forty-two degrees; now clinging to the timbers at the side; (to prevent the lubricity of our footing from taking advantage of the back part of our head, and making us to "see stars in a dark passage", from the tripping up of our heels) now winding among props, and over cast-iron pump tubes; now making our way from one side of the inclined shaft to the other, to enable us to travel as easy as possible . . . we again cross[ed] over to, and enter[ed] a side drift. . . .

Now, reader, let us rest for a moment, and look around a little. . . . Except for the lights in our hands all is dark, and as still almost as the tomb, with the exception of the distant creaking of a pump, and the steady dripping of some water at our elbow. Rock here, there, and everywhere. For several years men have been picking and drilling and blasting through solid rock; by day and night; in winter and in summer; led forward by the talismanic power of gold—or at least by the hope to obtain it. Hard rock, hard work and often very hard prospects; although combined with difficulty and danger, have never for a moment daunted or dismayed them. Above ground or under; by daylight or candle light—onward—ever onward—has been their unswerving resolve—and the guiding star of hope has ever shown with cheering light upon their labors. May the reward be near.

"As it is getting rather chilly, suppose we ascend."

"All right; shall we ascend by the ladder, or by the same way that we came?" inquired our excellent guide.

"Oh, by the ladder, by all means," was the response.

Lights were then fastened on our hats; as "in ascending we shall have need of both hands perhaps!" suggested our guide.

"What pleasure there is in seeing daylight after one has been for some time in darkness; and inhaling the cool fresh air above ground after some time spent underneath," we remarked, as we wiped the sweat from our brow, when we had reached the top.

While we cool ourselves, as we see the carts are busy in removing the gold-bearing quartz which has been taken from below, let us follow them to the mill and there see the *modus operandi* of crushing the rock and extracting the gold.

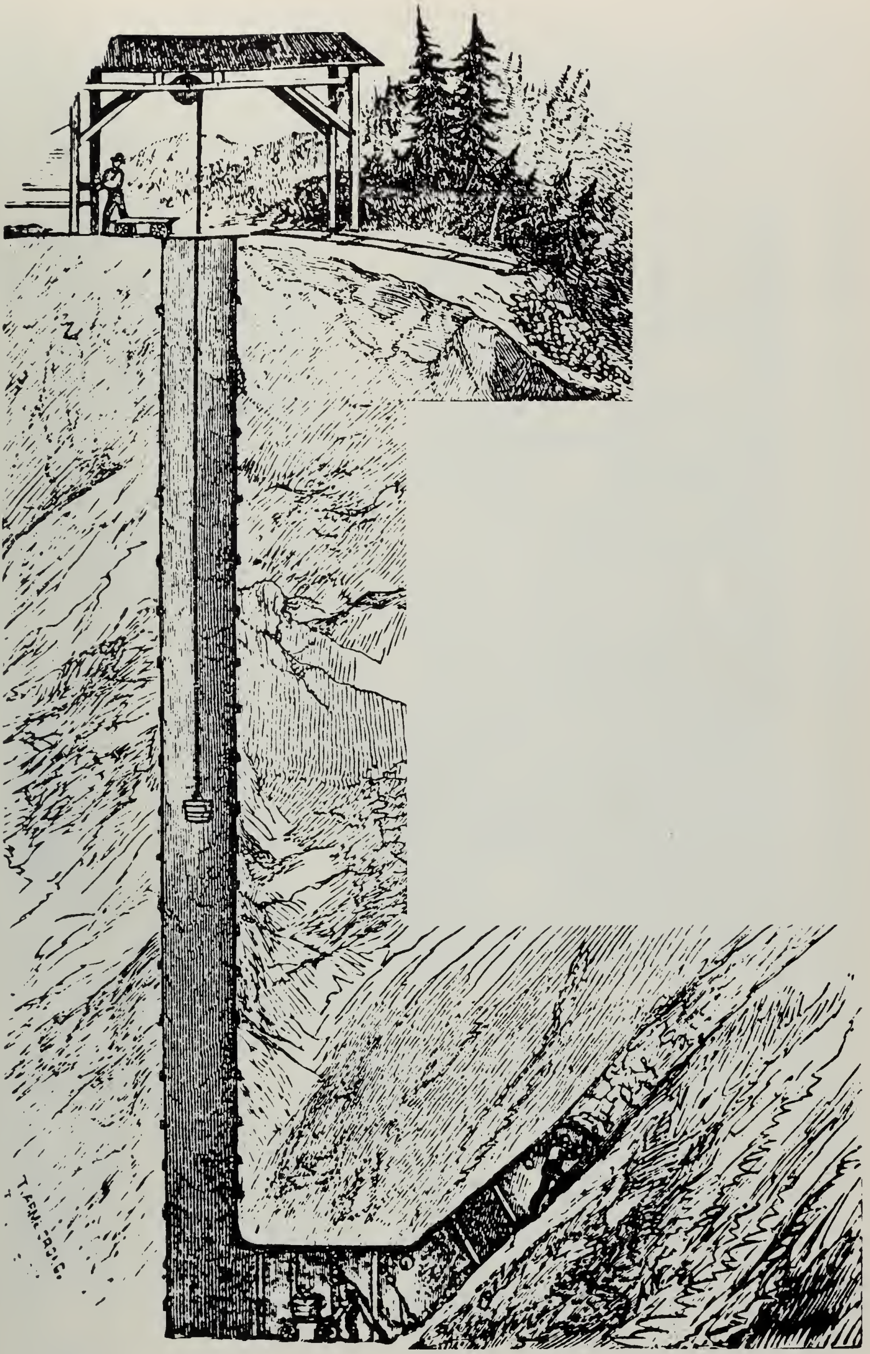
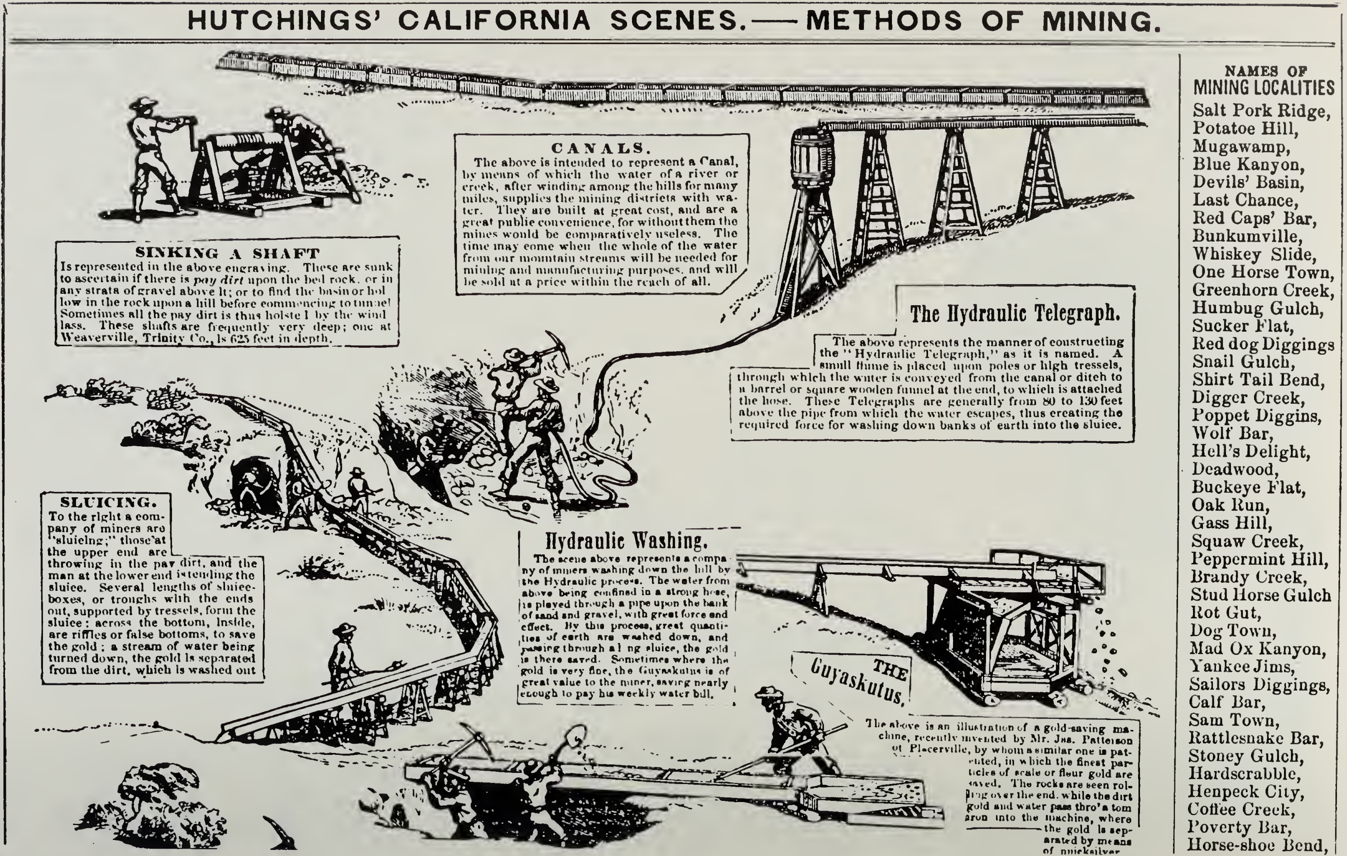


FIGURE 33. QUARRYING QUARTZ AT THE VEIN: T. Armstrong. Photo after Hutchings' California Magazine, 1857, by courtesy of California Historical Society, San Francisco.



HUTCHINGS' CALIFORNIA SCENES.—METHODS OF MINING.

SINKING A SHAFT

Is represented in the above engraving. These are sunk to ascertain if there is *pay dirt* upon the bed rock. or in any strata of gravel above it; or to find the basin or hollow in the rock upon a hill before commencing to tunnel Sometimes all the pay dirt is thus hoisted by the windlass. These shafts are frequently very deep; one at Weaverville, Trinity Co., is 625 feet in depth.

CANALS.

The above is intended to represent a Canal, by means of which the water of a river or creek, after winding among the hills for many miles, supplies the mining districts with water. They are built at great cost, and are a great public convenience, for without them the mines would be comparatively useless. The time may come when the whole of the water from our mountain streams will be needed for mining and manufacturing purposes, and will be sold at a price within the reach of all.

The Hydraulic Telegraph.

The above represents the manner of constructing the "Hydraulic Telegraph," as it is named. A small flume is placed upon poles or high tressels, through which the water is conveyed from the canal or ditch to a barrel or square wooden funnel at the end, to which is attached the hose. These Telegraphs are generally from 80 to 130 feet above the pipe from which the water escapes, thus creating the required force for washing down banks of earth into the sluice.

SLUICING.

To the right a company of miners are "sluicing;" those at the upper end are throwing in the pay dirt, and the man at the lower end is tending the sluice. Several lengths of sluice-boxes, or troughs with the ends out, supported by tressels, form the sluice; across the bottom, inside, are riffles or false bottoms, to save the gold; a stream of water being turned down, the gold is separated from the dirt, which is washed out

Hydraulic Washing.

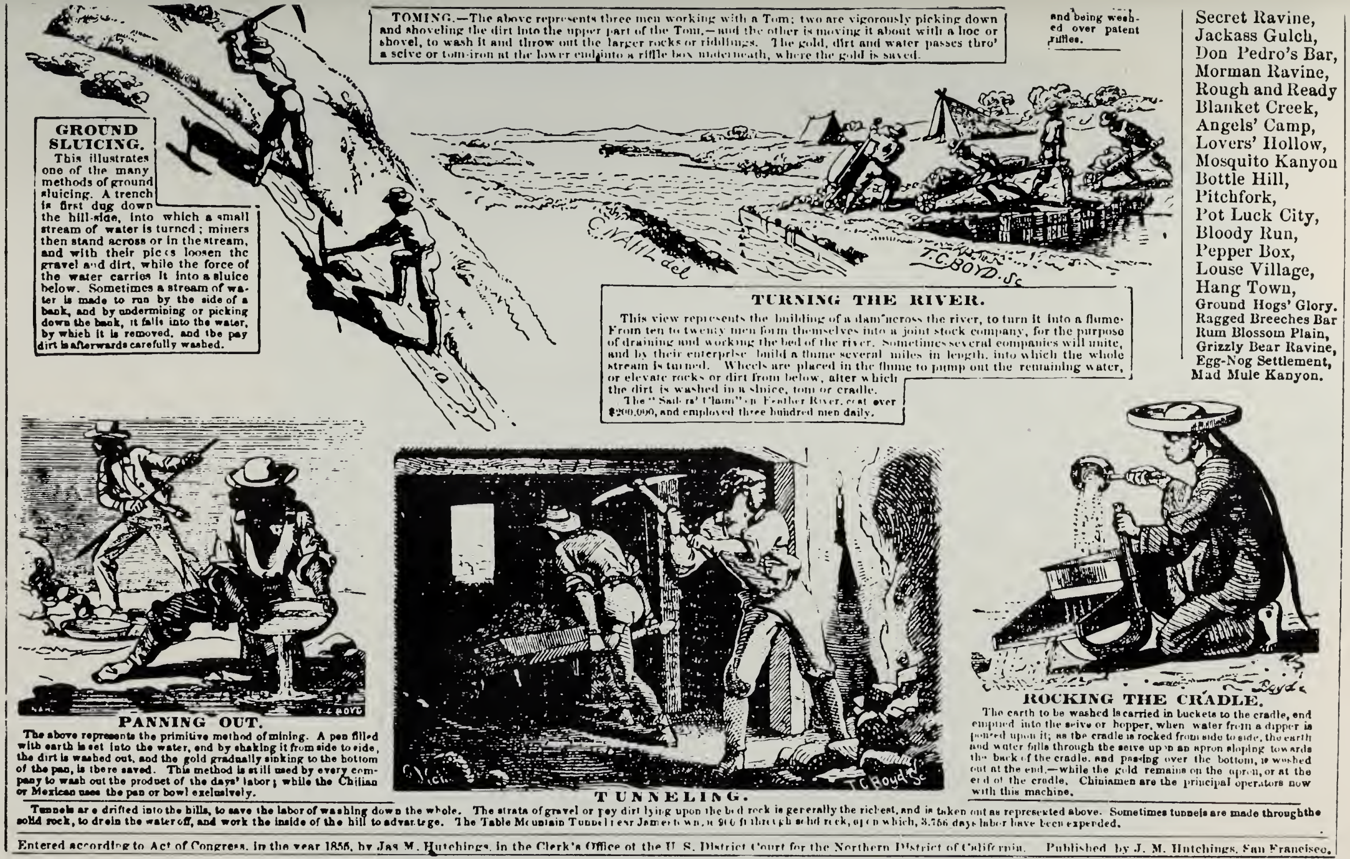
The scene above represents a company of miners washing down the hill by the Hydraulic process. The water from above being confined in a strong hose, is played through a pipe upon the bank of sand and gravel, with great force and effect. By this process, great quantities of earth are washed down, and passing through a long sluice, the gold is there saved. Sometimes where the gold is very fine, the Guyaskutus is of great value to the miner, saving nearly enough to pay his weekly water bill.

THE Guyaskutus,

The above is an illustration of a gold-saving machine, recently invented by Mr. Jas. Patterson of Placerville, by whom a similar one is patented, in which the finest particles of scale or flour gold are saved. The rocks are seen rolling over the end, while the dirt gold and water pass thro' a tom iron into the machine, where the gold is separated by means of quicksilver

NAMES OF MINING LOCALITIES

Salt Pork Ridge,
Potatoe Hill,
Mugawamp,
Blue Kanyon,
Devils' Basin,
Last Chance,
Red Caps' Bar,
Bunkumville,
Whiskey Slide,
One Horse Town,
Greenhorn Creek,
Humbug Gulch,
Sucker Flat,
Red dog Diggings
Snail Gulch,
Shirt Tail Bend,
Digger Creek,
Poppet Diggins,
Wolf Bar,
Hell's Delight,
Deadwood,
Buckeye Flat,
Oak Run,
Gass Hill,
Squaw Creek,
Peppermint Hill,
Brandy Creek,
Stud Horse Gulch
Rot Gut,
Dog Town,
Mad Ox Kanyon,
Yankee Jims,
Sailors Diggings,
Calf Bar,
Sam Town,
Rattlesnake Bar,
Stoney Gulch,
Hardscrabble,
Henpeck City,
Coffee Creek,
Poverty Bar,
Horse-shoe Bend,


C. NAHL del
T.C. BOYD. Sc
T.C. BOYD
T.C. Boyd. Sc
Boyd

TOMING.—The above represents three men working with a Tom; two are vigorously picking down and shoveling the dirt into the upper part of the Tom,—and the other is moving it about with a hoe or shovel, to wash it and throw out the larger rocks or riddlings. The gold, dirt and water passes thro' a seive or tom-iron at the lower end into a riffle box underneath, where the gold is saved.

and being washed over patent riffles.

Secret Ravine,
Jackass Gulch,
Don Pedro's Bar,
Morman Ravine,
Rough and Ready
Blanket Creek,
Angels' Camp,
Lovers' Hollow,
Mosquito Kanyon
Bottle Hill,
Pitchfork,
Pot Luck City,
Bloody Run,
Pepper Box,
Louse Village,
Hang Town,
Ground Hogs' Glory.
Ragged Breeches Bar
Rum Blossom Plain,
Grizzly Bear Ravine,
Egg-Nog Settlement,
Mad Mule Kanyon.

GROUND SLUICING.

This illustrates one of the many methods of ground sluicing. A trench is first dug down the hill-side, into which a small stream of water is turned; miners then stand across or in the stream, and with their picks loosen the gravel and dirt, while the force of the water carries it into a sluice below. Sometimes a stream of water is made to run by the side of a bank, and by undermining or picking down the bank, it falls into the water, by which it is removed, and the pay dirt is afterwards carefully washed.

TURNING THE RIVER.

This view represents the building of a dam across the river, to turn it into a flume. From ten to twenty men form themselves into a joint stock company, for the purpose of draining and working the bed of the river. Sometimes several companies will unite, and by their enterprise build a flume several miles in length, into which the whole stream is turned. Wheels are placed in the flume to pump out the remaining water, or elevate rocks or dirt from below, after which the dirt is washed in a sluice, tom or cradle.

The "Sailors' Claim" on Feather River, cost over $200,000, and employed three hundred men daily.

PANNING OUT.

The above represents the primitive method of mining. A pan filled with earth is set into the water, and by shaking it from side to side, the dirt is washed out, and the gold gradually sinking to the bottom of the pan, is there saved. This method is still used by every company to wash out the product of the days' labor; while the Chilian or Mexican uses the pan or bowl exclusively.

TUNNELING.

Tunnels are drifted into the hills, to save the labor of washing down the whole. The strata of gravel or pay dirt lying upon the bed rock is generally the richest, and is taken out as represented above. Sometimes tunnels are made through the solid rock, to drain the water off, and work the inside of the hill to advantage. The Table Mountain Tunnel near Jamestown, is 900 ft through solid rock, upon which, 3.756 days labor have been expended.

ROCKING THE CRADLE.

The earth to be washed is carried in buckets to the cradle, and emptied into the seive or hopper, when water from a dipper is poured upon it; as the cradle is rocked from side to side, the earth and water falls through the seive upon an apron sloping towards the back of the cradle, and passing over the bottom, is washed out at the end,—while the gold remains on the apron, or at the end of the cradle. Chiniamen are the principal operators now with this machine.

Entered according to Act of Congress, in the year 1855, by Jas M. Hutchings, in the Clerk's Office of the U. S. District Court for the Northern District of California. Published by J. M. Hutchings, San Francisco.

FIGURE 34. HUTCHINGS' CALIFORNIA SCENES.—METHODS OF MINING. 1855. Photo by courtesy of Wells Fargo Bank & Union Trust Co., San Francisco.

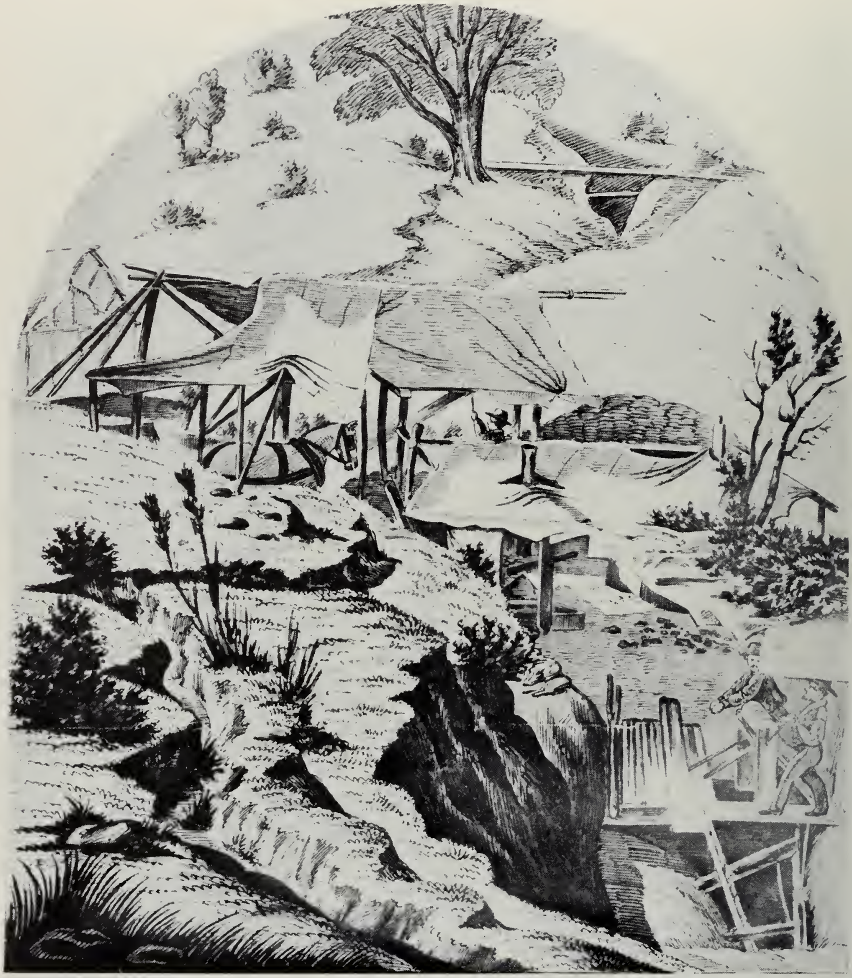


FIGURE 35. OUTSIDE VIEW OF SHAFT NO. 1 OF BEN MOCK & SEALE'S SECTION OF THE "MARIPOSA VEIN". A "POCKET" OF $26,000 WAS STRUCK HERE ON THE 14TH OF JULY 1859, AT A DEPTH OF 40 FT BY F. HOWELL & LIND BROTH., WORKING SAID SHAFT ON SHARES: Mariposa, 1859; From Nature by A. Schwartz. Photo from drawing by courtesy of Sutter's Fort Historical Museum, Sacramento.

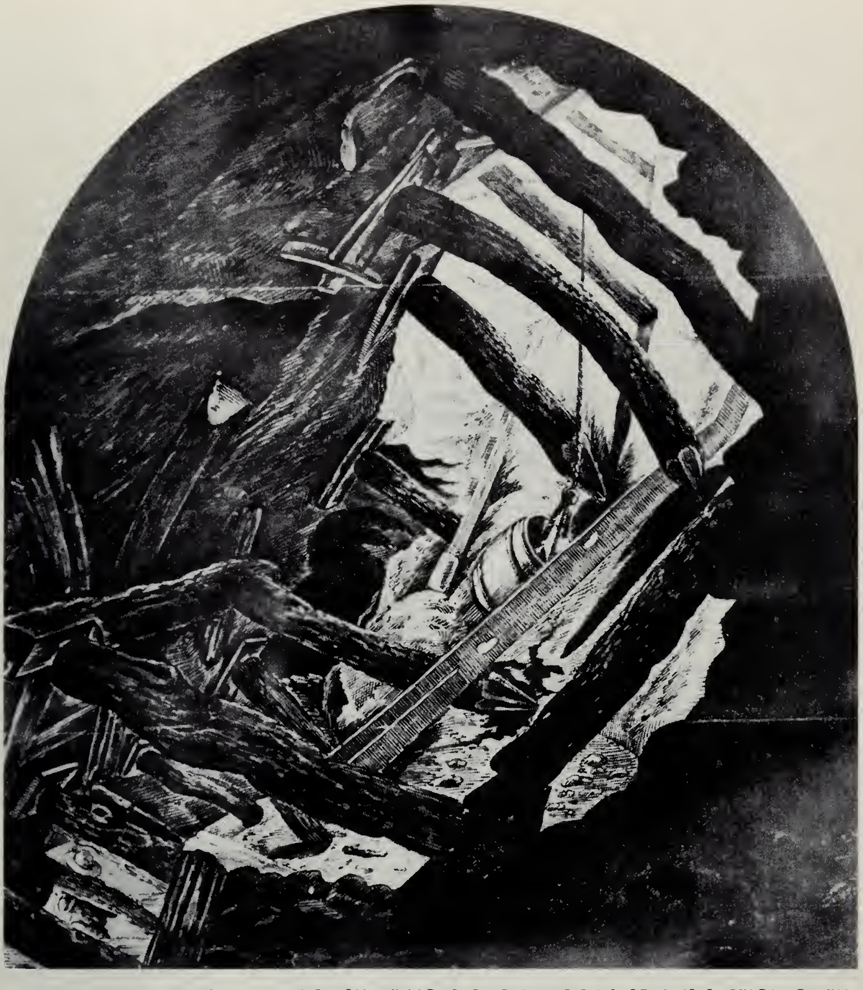


FIGURE 36. INSIDE VIEW OF SHAFT NO. 1 OF BEN MOCK & SEALE'S SECTION OF THE "MARIPOSA VEIN". A "POCKET" OF $26,000 WAS STRUCK HERE ON THE 14TH OF JULY 1859, AT A DEPTH OF 40 FT BY F. HOWELL & LIND BROTH., WORKING SAID SHAFT ON SHARES: Mariposa, 1859; From Nature by A. Schwartz. Photo from drawing by courtesy of Sutter's Fort Historical Museum, Sacramento.

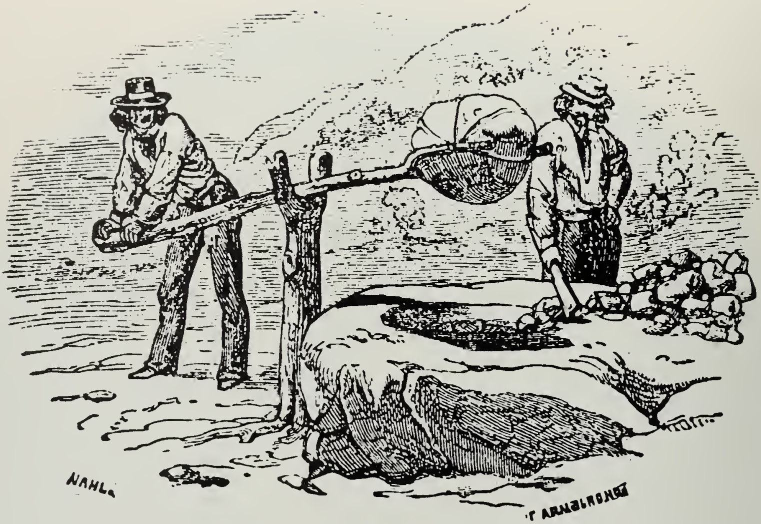


FIGURE 37. MEXICANS BREAKING THE QUARTZ: C. Nahl; T. Armstrong. Photo after Hutchings' California Magazine, 1857, by courtesy of California Historical Society, San Francisco.

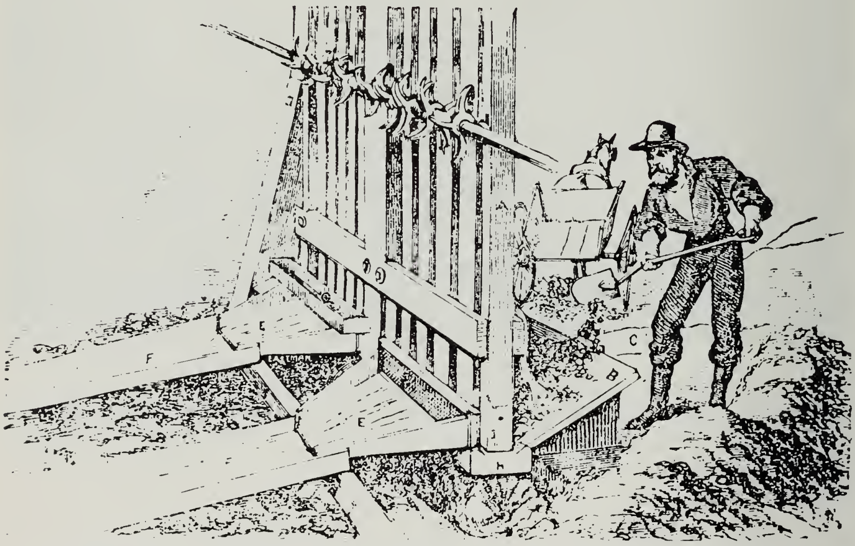


FIGURE 38. FEEDING THE MILL. Photo after Hutchings' California Magazine, 1857, by courtesy of California Historical Society, San Francisco.

After the quartz is emptied from the cart into the yard, the large pieces are broken by hand to about the size of a man's fist or a little smaller; they are then shoveled, with the dust and finer portions of rock, upon an inclined table or "hopper" at B, on which a small stream of water is conveyed through a pipe from above, and by which the quartz is washed down the hopper to a solid cast-iron bed-plate at H, and beneath the stampers [see fig. 38].

The stampers at A and I being elevated by convex arms attached to a revolving shaft at K, when at the required height, fall suddenly down upon the quartz; and being shod with heavy cast-iron, which, added to the stampers, make the whole weight of a single one from six hundred to a thousand pounds, crushes the rock to powder upon which it falls.

In front of the stampers at D is a very fine seive or screen, against and through which the water, gold and pulverized quartz are constantly being splashed by the falling of the stampers; and should the rock not be pulverized sufficiently fine to pass through these discharge-screens it again falls back upon the bed-plate to receive another crushing from the stampers. If, however, it is reduced fine enough to pass through, it falls upon an apron at E, or into an "amalgamating box" containing quicksilver, and into which a dash-board is inserted that all the water, gold, and tailings may pass *through* the quicksilver contained in the amalgamating box, to an inclined plane or blanket-table below. Across and above the apron, or amalgamating box, a small trough is fixed at O, with holes in the bottom, for the purpose of distributing clean water equally on the apron, or into the amalgamating box, and by which the pulverized rock, and gold not saved above, is washed down to the blanket-tables at F.

These tables simply consist of a flat sluice, generally about two feet in width by six inches in depth, and upon which a coarse blanket is spread for the purpose, principally, of saving the auriferous sulphurets, and which will not amalgamate with the quicksilver. Some companies, however, depend chiefly upon the apron for saving the whole of their gold, and do not use quicksilver above the blanket-tables.

The blankets are allowed to remain upon the tables from ten to thirty minutes, according to the quality of the rock being crushed; that which is rich requiring the change about every ten or fifteen minutes, and that which is poor every twenty or thirty minutes. When a change is desirable the blankets are carefully rolled up and placed in a bucket, or small tub, and carried to the "vat"—not, however, before another is spread upon the table—where they are carefully washed. In order to test the quality of the rock being crushed, the contents of the blanket are frequently washed into a *batea*, or broad Mexican bowl, and prospected.

The materials contained in the blanket vats are saved in a box made for that purpose, or thrown into a heap, or taken at once to some kind of amalgamating machine—and there is scarcely a couple of mills in the State where the same process exactly is used; as each superintendent of a mill supposes that he has made some improvements in *his* mill entirely unknown or unpracticed by others; at all events he flatters himself that *he* saves more gold than his neighbor.

The processes most commonly in use are the *Rastra* and Chili mill. . . .

One of the first used, as well as one of the most useful and most important, is the Mexican Rastra. Though rude in its construction and simple in its working, it is one of the most effectual methods of saving the gold which has yet been discovered. The Mexican method of constructing these is to lay a circular track of stone tolerably level with a low wall around the outside of the track;

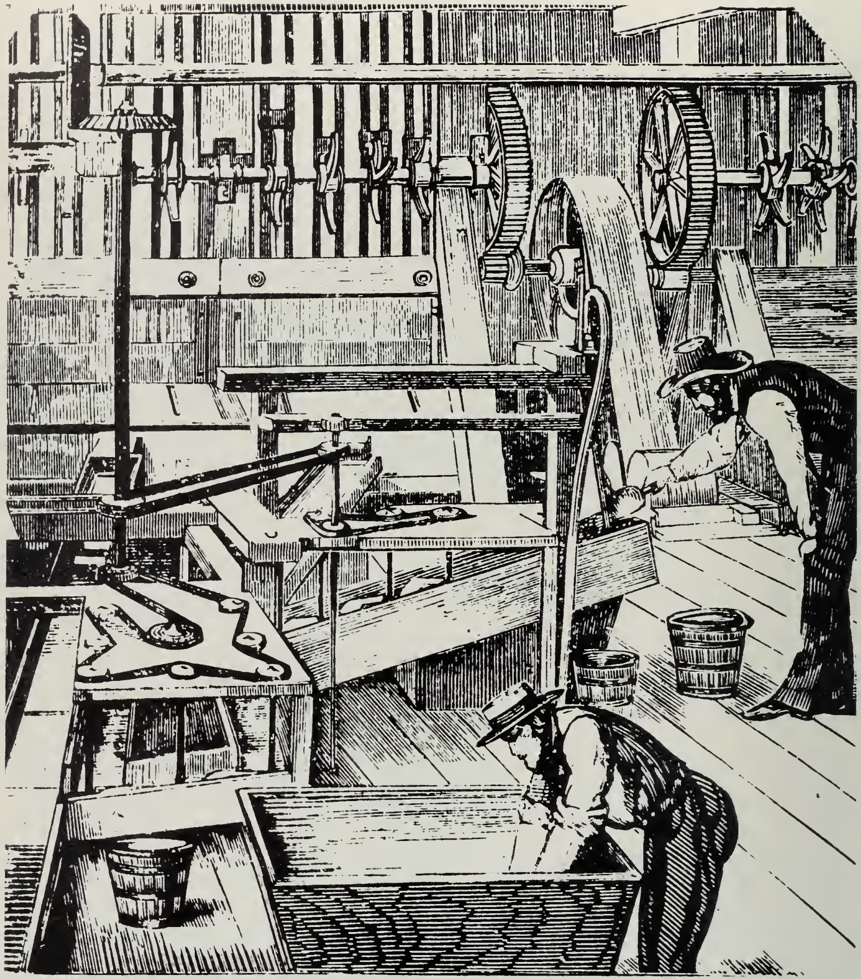


FIGURE 39. INTERIOR OF A QUARTZ MILL, IN GRASS VALLEY. Photo after Hutchings' California Magazine, 1857, by courtesy of Sutter's Fort Historical Museum, Sacramento.

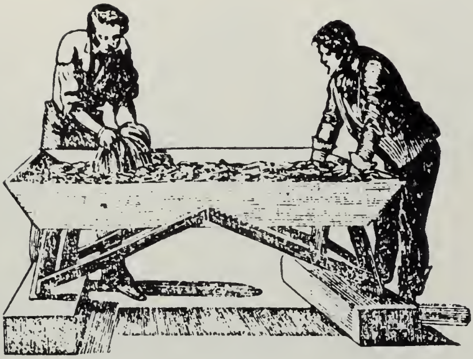


FIGURE 40. WASHING THE BLANKETS. Photo after Hutchings' California Magazine, 1857, by courtesy of California Historical Society, San Francisco.

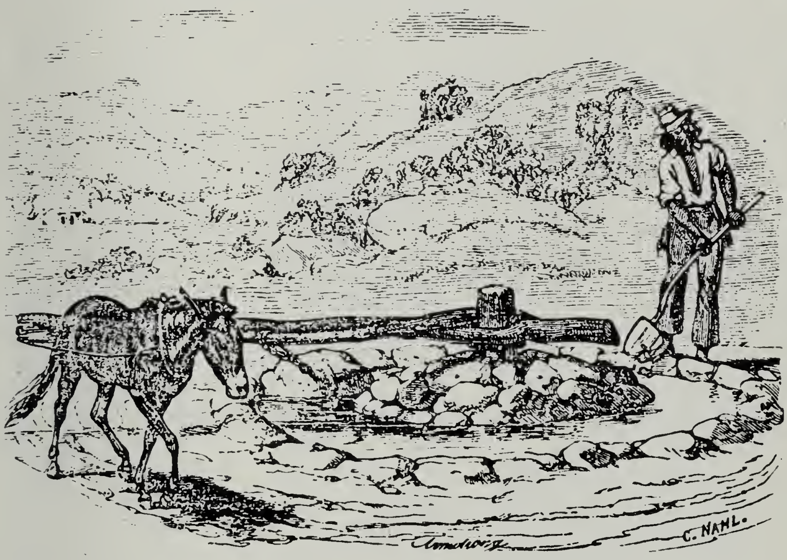


FIGURE 41. THE MEXICAN RASTRA: C. Nahl; T. Armstrong. Photo after Hutchings' California Magazine, 1857, by courtesy of California Historical Society, San Francisco.

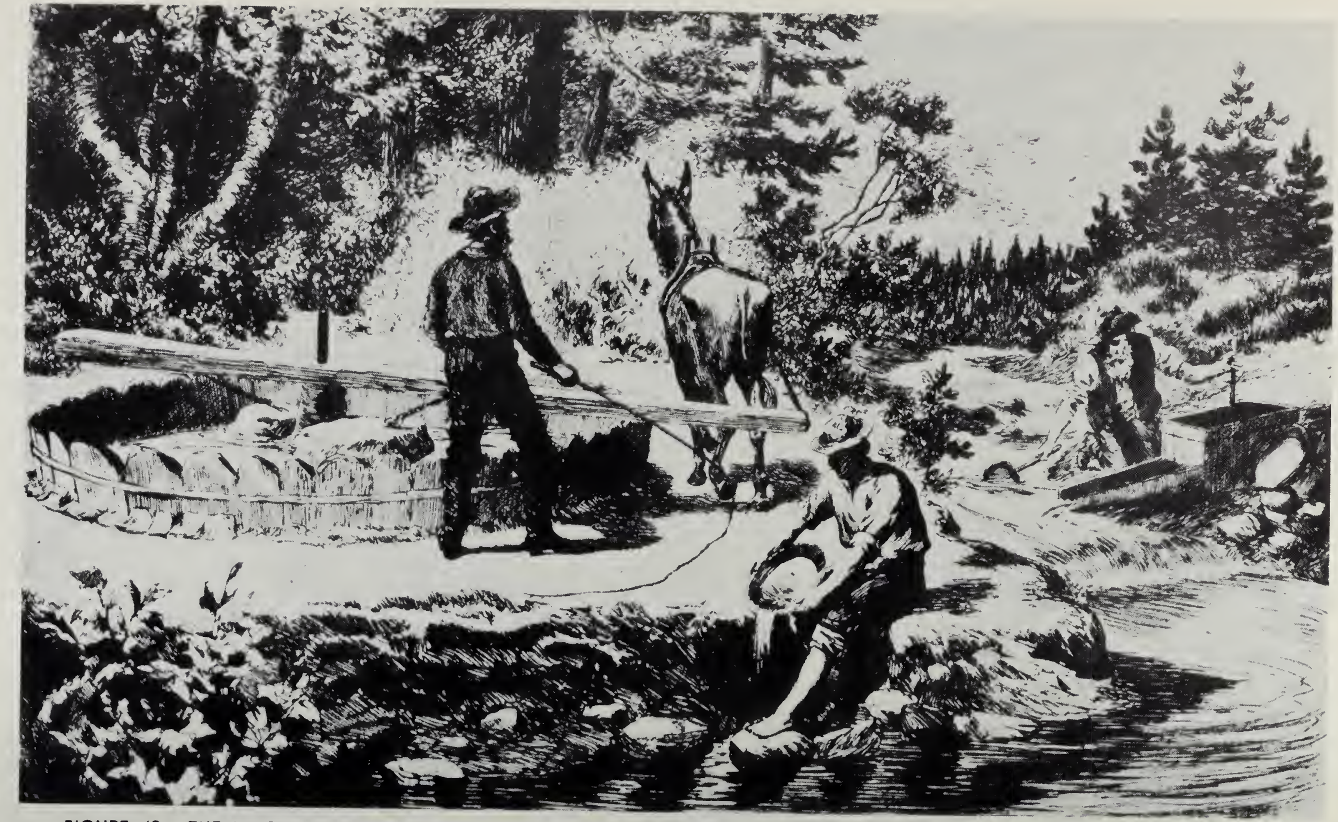


FIGURE 42. THE ARASTRA, OR PRIMITIVE QUARTZ MILL. Photo after *A Pictorial History of California*, by Owen C. Coy, by courtesy of University of California Extension Division, Berkeley, and Wells Fargo Bank & Union Trust Co., San Francisco.

and in the centre a post made of a tree cut off at the required height, and generally just above a crotch or arm; another small tree is then cut in the shape required, for making a horizontal shaft; to this is attached one or more large stones; and these being drawn around by donkey or mule power, grind the quartz to powder. Of course, as gold is the heaviest it naturally seeks the lowest places, and as quicksilver is always put in with the quartz the gold becomes amalgamated with it.

The Mexican rastra has been improved some little in its construction and adaptation to our wants,—and in many cases mule-power has been superseded by steam; but the principle remains about the same.

When the rastra is properly prepared, a "batch" of about five hundred pounds is generally emptied into one about ten feet in diameter; but the quantity is always regulated by the size of the machine. It is then ground very fine by means of the drag-stones attached to arms fixed in the perpendicular shaft, and which are generally given about eight revolutions per minute. At this rate it will require from three to four hours to grind a batch sufficiently; but this is somewhat regulated by the grit and weight of the drag-stones. About three quarters of an hour before the whole is thoroughly ground, a sufficient quantity of quicksilver is added; but the amount is regulated by the richness of the quartz in process of grinding. If, for instance, the five hundred pounds of tailings placed in the arastra is supposed to contain about three quarters of an ounce of gold, about one ounce of quicksilver is generally used —or about twenty-five per cent. more of the latter than the former. Some judgment is required in this—too much quicksilver being a disadvantage, inasmuch as the amalgam should be kept hard to make it effectual in saving the gold. Quicksilver should also be kept very free from grease, as it cannot be too clean; and should invariably be well retorted every time it is used.

About ten minutes before the grinding is finished, about sixteen buckets of water are poured into the rastra, to the quantity named, and the same motion continued, the whole appearing like muddy water. This is then baled out, or run off quickly. Five hundred pounds more of the quartz are then added, and the process repeated, adding the same portion of quicksilver to every batch.

This is kept on for one, two, three, or four weeks, according to the richness of the quartz, or the taste and wants of the owner. The larger the amount of amalgam contained in the rastra, the more gold is there saved, in proportion, to the ton.

The amalgam is then taken out of the crevices in the bottom of the rastra, and carefully panned out, and as carefully retorted. After this, most business men melt the gold into bars or ingots, before sending it to the mint to be coined.

Before commencing to grind again, the crevices between the stones covering the floor of the rastra, about one and a half inches wide, are tightly packed and filled with clay, level with the stone.

In El Dorado County, rastras sixteen feet in diameter are used to great advantage, as more than double the amount of quartz is ground by them than by the smaller ones; but of course they require a proportionate increase in power to work them.

It should also be remembered that not less than two fifths more quartz is ground in the same rastra when worked by steam or water-power than when worked by animals, inasmuch as the speed and regularity is increased.

It should also be well remembered by every operator in quartz, that warm water is of great assistance in every thing connected with amalgam, as it will

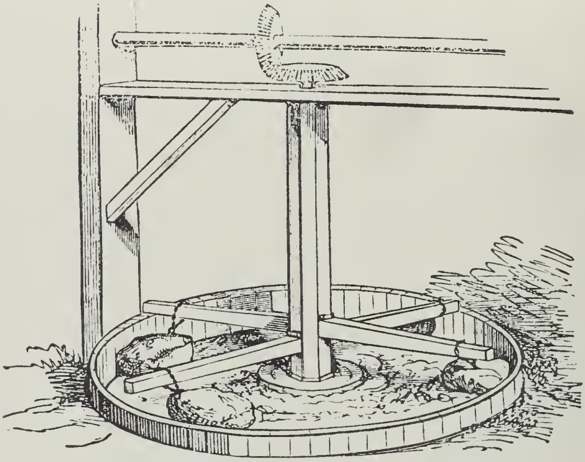


FIGURE 43. THE IMPROVED MEXICAN RASTRA. Photo after Hutchings' California Magazine, 1857, by courtesy of California Historical Society, San Francisco.

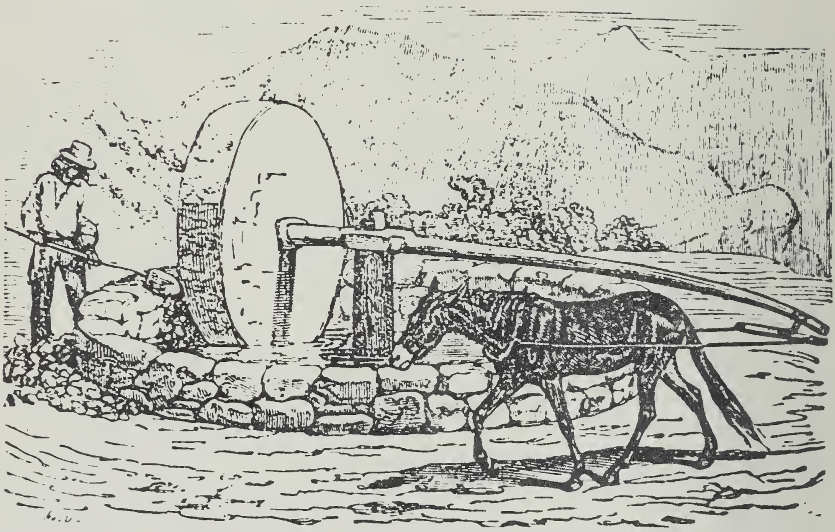


FIGURE 44. THE CHILI MILL: C. Nahl. Photo after Hutchings' California Magazine, 1857, by courtesy of California Historical Society, San Francisco.

be the means of saving from ten to fifteen per cent. more gold than when it is worked with cold water—a very important kind of economy.

This [Chili] mill, as used in Chili, and from whence its origin and name are derived, is nearly as simple in its construction as the rastra. It consists of a circular inclosure somewhat resembling the rastra, with the wall a little higher, and more regular; and, instead of the "drag-stones", a large stone wheel, attached to the horizontal shaft, is used for grinding the rock. Into this mill a small stream of water is constantly running, a portion of which is forced out at each revolution of the wheel. The gold is saved by means of quicksilver on the bottom of the mill, in the same manner as in the rastra.

To make this principle more subservient to the purposes of quartz mining, and better adapted to the requirements of a faster age and people, the "improved Chili Mill" was invented. This consists of two heavy cast-iron wheels, from three to five feet in diameter, and from ten to fifteen inches in thickness: these revolve on an axle, moving steadily round in a circular iron basin about a foot in depth, into which the tailings from the blanket tables are conveyed, and ground to powder.

As these improved mills are generally worked by steam, the speed attained, and work accomplished, of course very far exceeds the old process. . . .

The methods of saving the gold which passes over the blankets in the tailings, are almost as numerous as are the mills where the quartz is crushed. The principle, however, is to allow the tailings to run down a series of inclined tables, or sluices, at the end of each of which is often placed a wood trough, or iron pan, containing quicksilver, into which they flow, when the gold falls into the quicksilver on the bottom, and is there retained; while the lighter material floats over the edge of the trough or pan into another sluice, at the end of which is another pan, where the same process is repeated. The sluices, or inclined tables, are generally fitted up with "patent riffles" across the bottom, filled with quicksilver. After the tailings have passed through the whole series of sluices they are sometimes worked through the improved Chili Mill, or other machine; but are oftener allowed to run into a large vat, from which the water flows off while the tailings settle at the bottom. These are then thrown into a heap and allowed to "rust", preparatory to other processes at some future time.

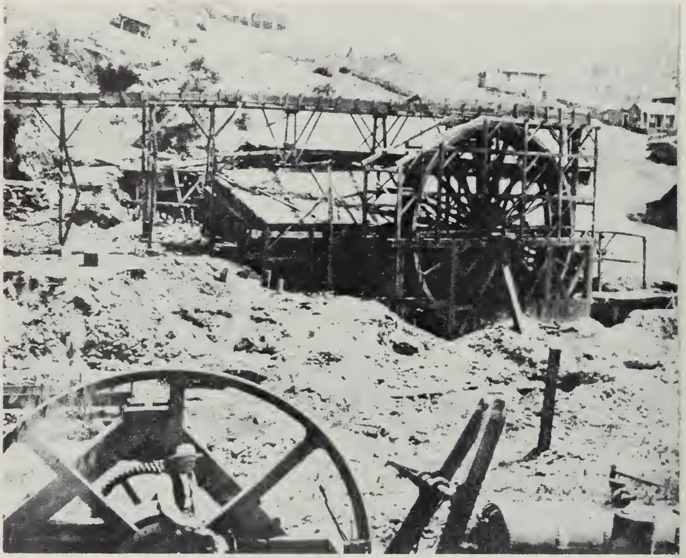


FIGURE 45. THE FIRST QUARTZ CRUSHING MILL ERECTED IN CALIFORNIA—AMADOR CITY, 1850—AND THE BUILDER. Photo after *Mining Scenes in California,* illustrated by Edw. J. Muybridge, by courtesy of Sutter's Fort Historical Museum, Sacramento. (Ed. note: According to C. A. Logan, a stamp mill was crushing ore from the Mariposa mine, near the town of Mariposa, in Mariposa County, as early as July 1849; see *History of Mining and Milling Methods in California,* California Div. Mines Bull. 141, 1948.)

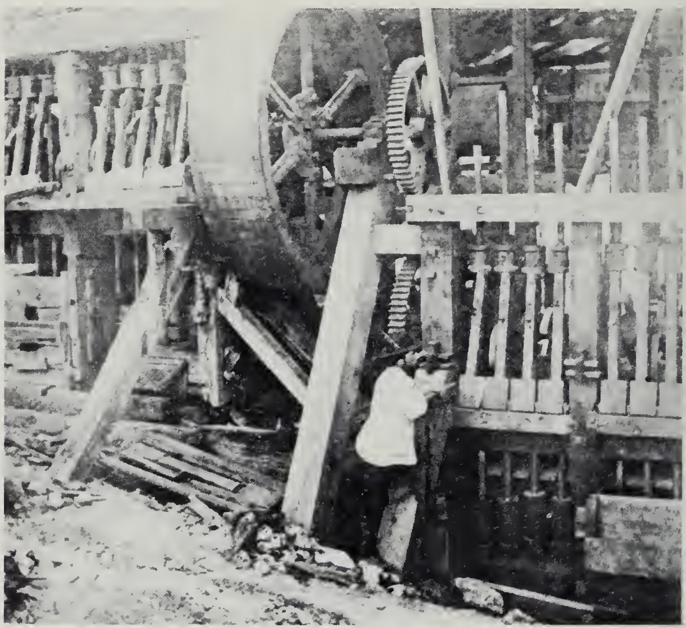
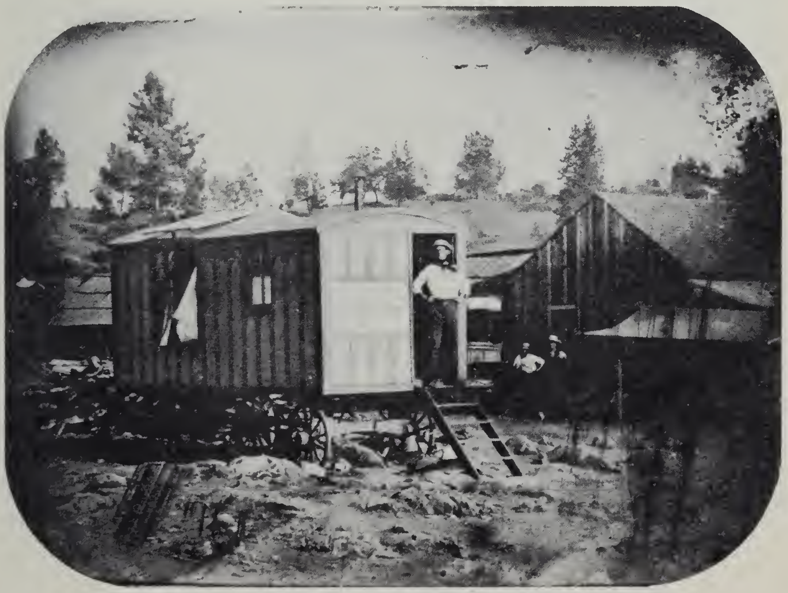
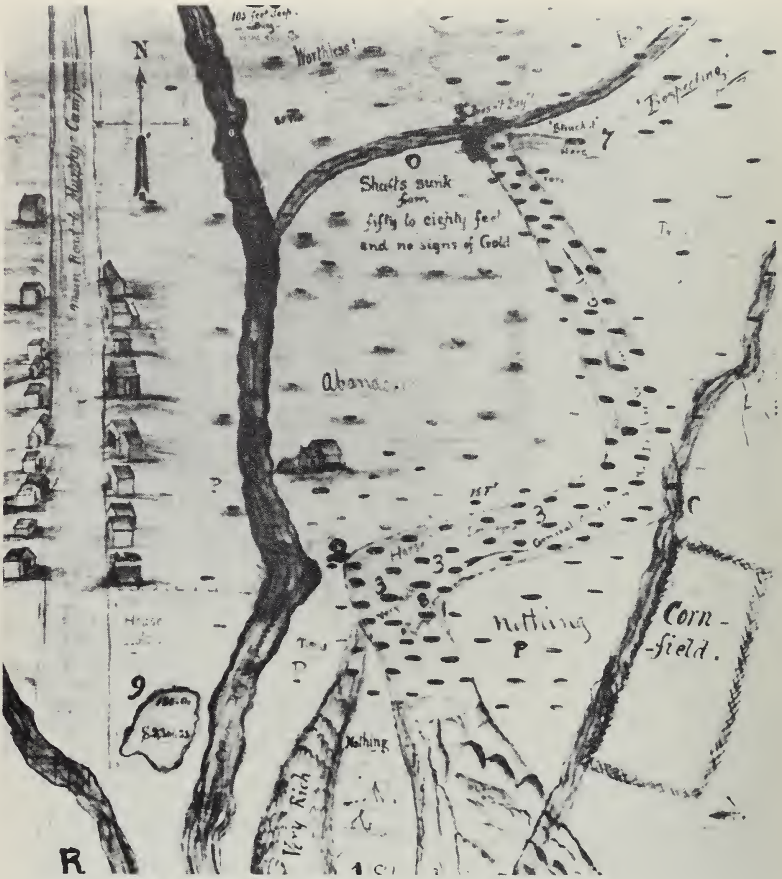


FIGURE 46. STAMPS OF THE FIRST QUARTZ CRUSHING MILL ERECTED IN CALIFORNIA—AMADOR CITY, 1851. Photo after *Mining Scenes in California,* illustrated by Edw. J. Muybridge, by courtesy of Sutter's Fort Historical Museum, Sacramento.

DAGUERREOTYPES AND AMBROTYPES TAKEN IN THE DIGGINGS



BATCHELDER'S DAGUERRIAN SALOON
"Walk in and examine specimens"



SKETCH MAP OF VALLECITA AND VICINITY

In the spring of 1852, the Daguerrian Saloon (shown on the preceding page) was set up by —— Batchelder and Isaac W. Baker at Vallecita, just east of Angels Camp. The sketch map (above) shows the location of this house on wheels, the first house on the right-hand side of the road running through Vallecita. Apparently the partners moved on to Murphy's in 1852, where the daguerreotypes reproduced in figures 63, 65, and 66 were made, and still later to Mokelumne Hill. Mr. Baker left California in the fall of 1853. The illustrations "Batchelder's Daguerrian Saloon" and "Sketch Map of Vallecita and Vicinity" are from the collection of Frederick S. Baker, Berkeley, and are reproduced herein by courtesy of Dr. Baker.

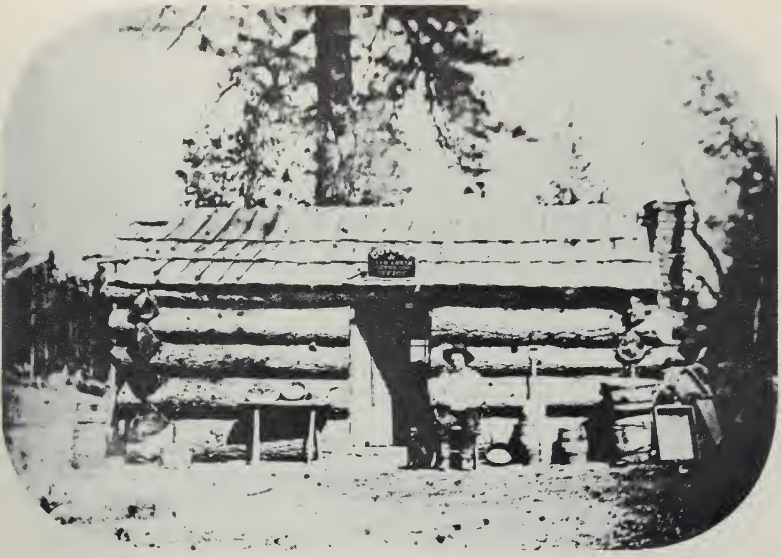


FIGURE 47. DEER CREEK WATER CO'S OFFICE. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

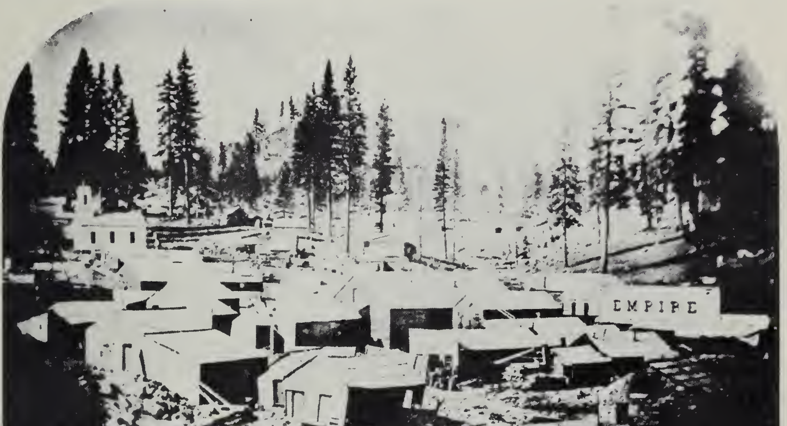


FIGURE 48. NEVADA CITY, CALA., 1852. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

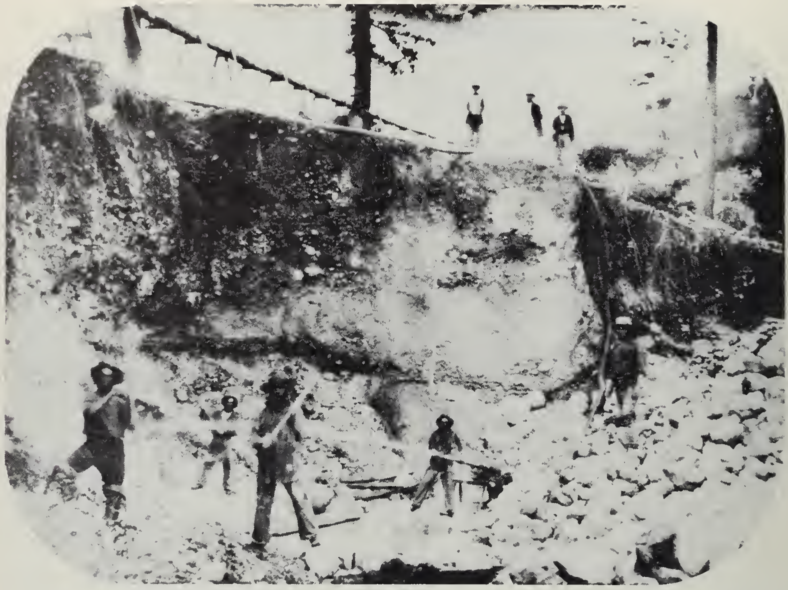


FIGURE 49. THE DIGGINGS, MICHIGAN BLUFF, 1854. Daguerreotype from the collection of Anson S. Blake, Richmond, California. The daguerreotypes represented in figures 49 and 50 were made for Charles T. Blake, first Wells Fargo agent at Michigan Bluff. Photo by courtesy of Wells Fargo Bank & Union Trust Co., San Francisco.

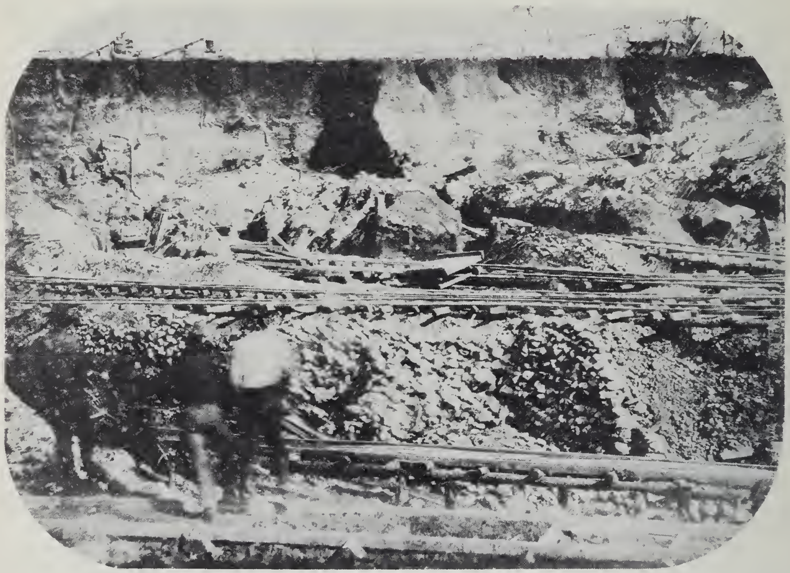


FIGURE 50. METHOD OF HANDLING BOULDERS, MICHIGAN BLUFF, 1854. Daguerreotype from the collection of Anson S. Blake, Richmond, California; photo by courtesy of Mr. Blake.

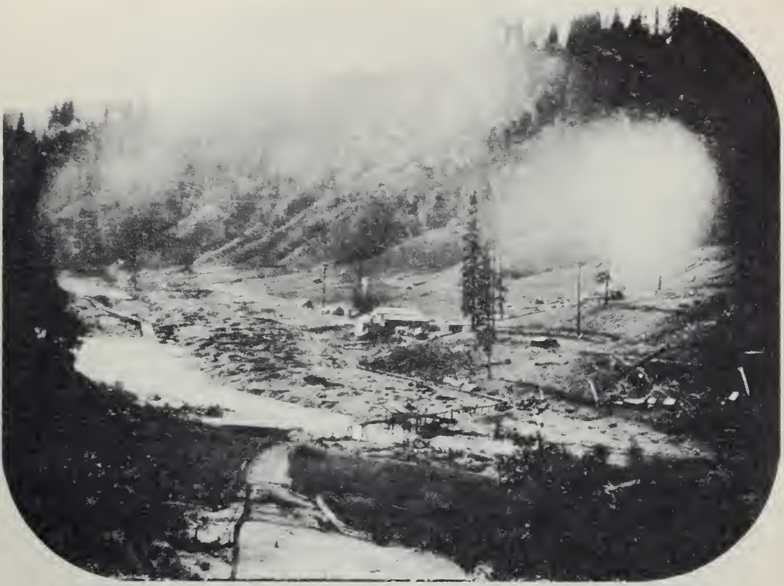


FIGURE 51. FOSTER'S BAR, NORTH FORK OF YUBA RIVER, IN THE EARLY FIFTIES. Daguerreotype, depository unknown; the original was sent by Charles E. De Long to his brother in New York State. Photo by courtesy of California Historical Society, San Francisco, after reproduction in *California's Bantam Cock—The Journal of Charles E. De Long, 1854-1863,* California Hist. Soc. Quart., vol. 11, p. 47.

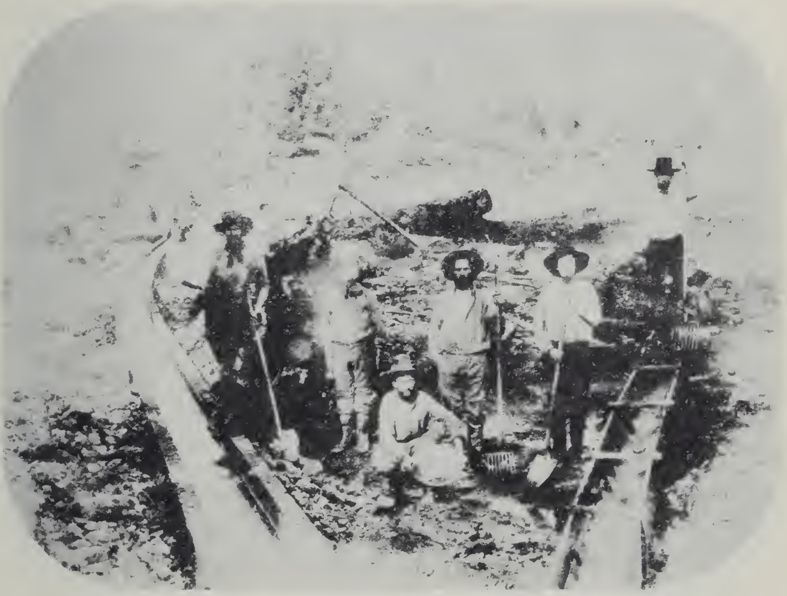


FIGURE 52. GARDEN VALLEY, EL DORADO COUNTY, ABOUT 1855. Daguerreotype, depository unknown. Left to right: Alec Moherter, —— Wing, H. W. Russell, Fred Isbell, —— Worley, Cy Spaulding. Photo by courtesy of Sutter's Fort Historical Museum, Sacramento.

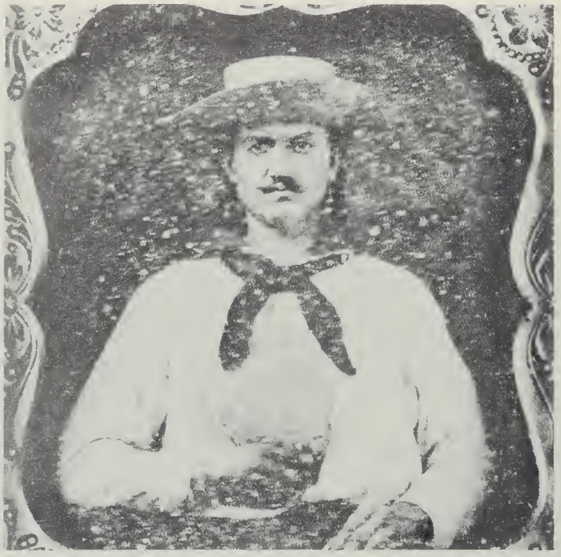


FIGURE 53. MINER WITH 8-POUND LUMP OF GOLD TAKEN FROM MINE NEAR SIERRAVILLE, SIERRA COUNTY. Ambrotype from the collection of Philip K. Bekeart, San Francisco; photo by courtesy of Mr. Bekeart.

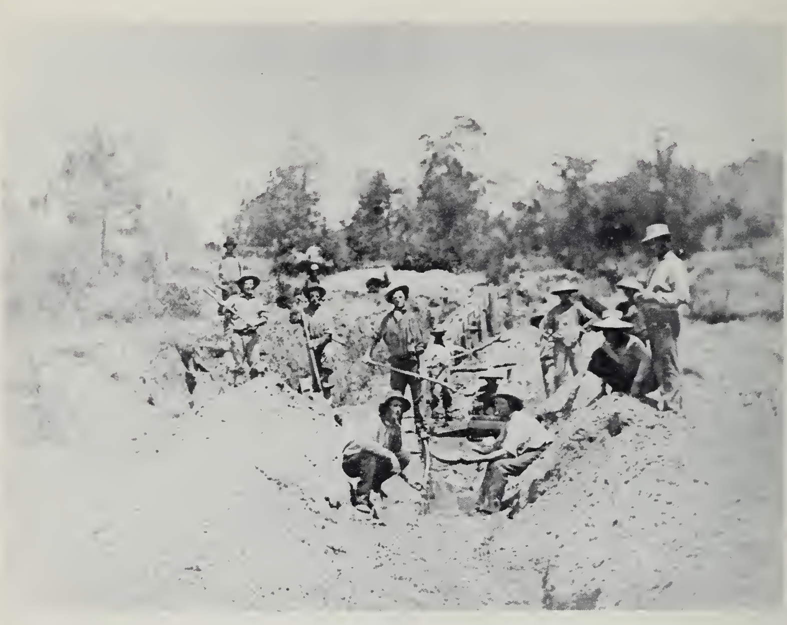


FIGURE 54. SLUICING AT COLOMA, NEAR SUTTER'S MILL, 1850-51. Ambrotype from the collectian of Philip K. Bekeart, San Francisco. Photo by caurtesy of Wells Farga Bank & Unian Trust Ca., San Francisco. Man with shovel in center of picture is Martin J. Allhoff.

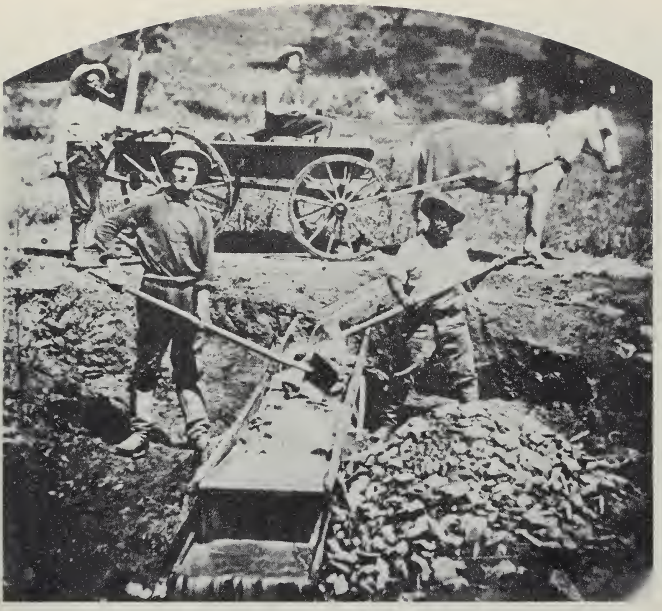


FIGURE 55. SPANISH FLAT, 1852. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

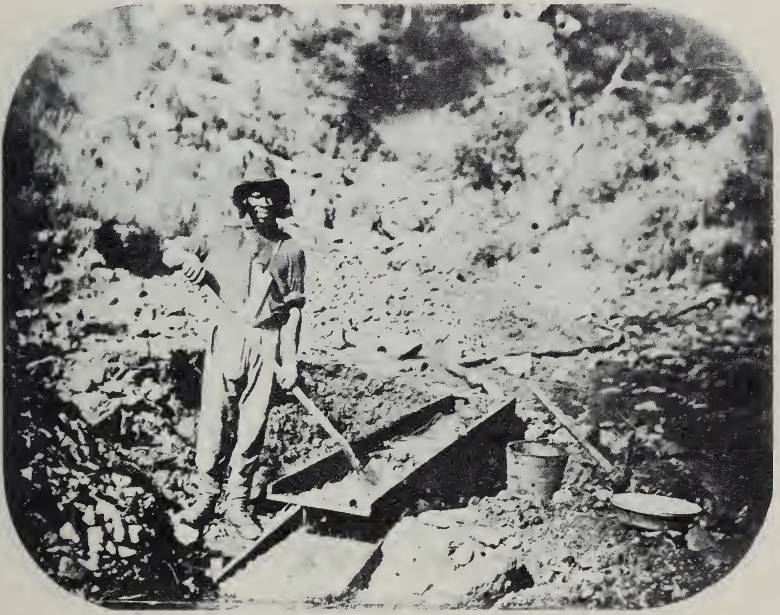


FIGURE 56. AUBURN RAVINE, 1852. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

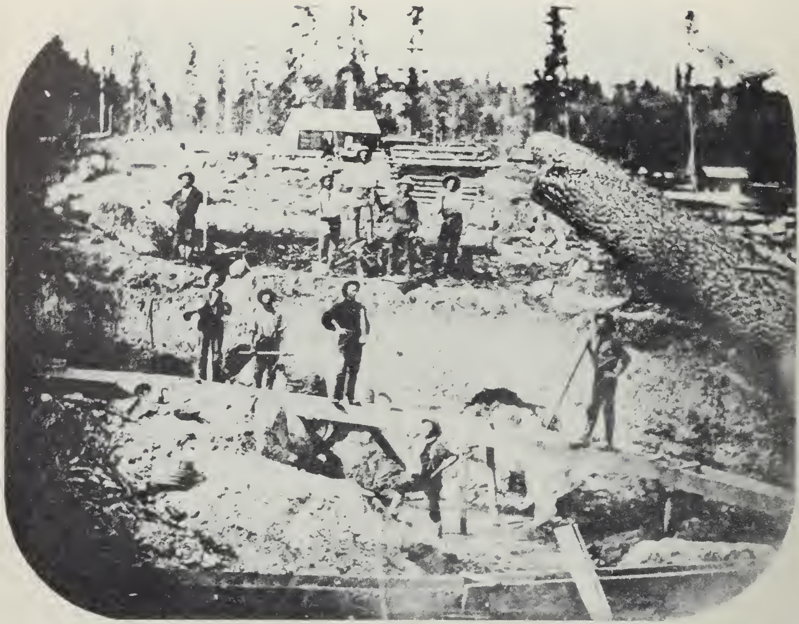


FIGURE 57. NEAR NEVADA CITY, 1852. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

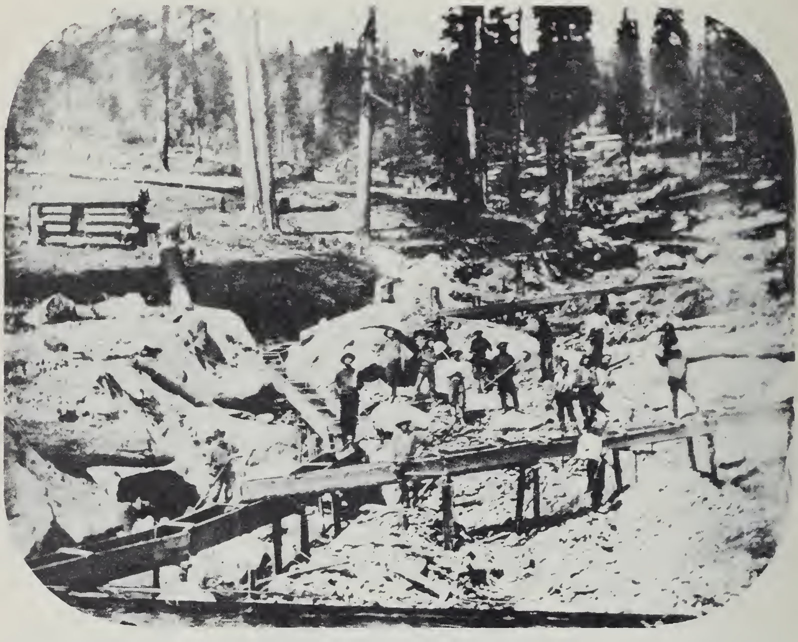


FIGURE 58. NEAR NEVADA CITY, 1852. Daguerreotype, depository unknown. Photo by courtesy of California State Library, California Section, Sacramento.

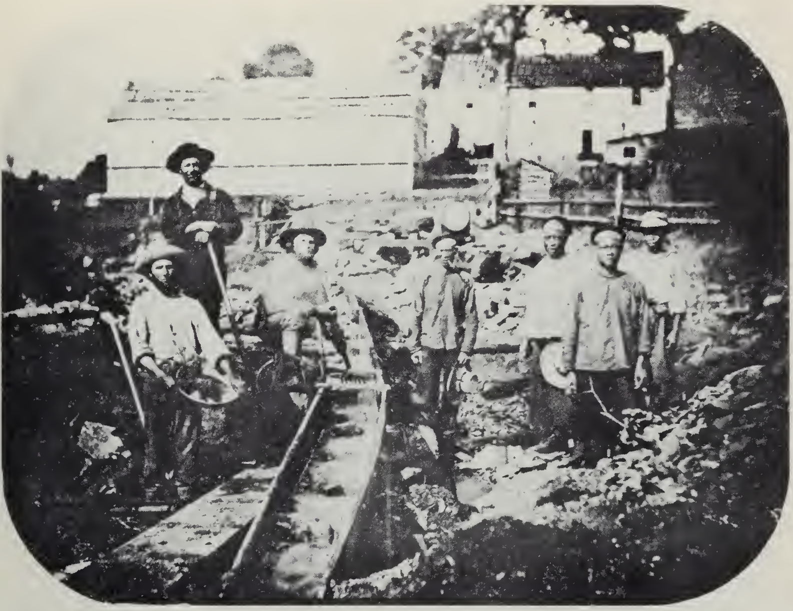


FIGURE 59. HEAD OF AUBURN RAVINE, 1852. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

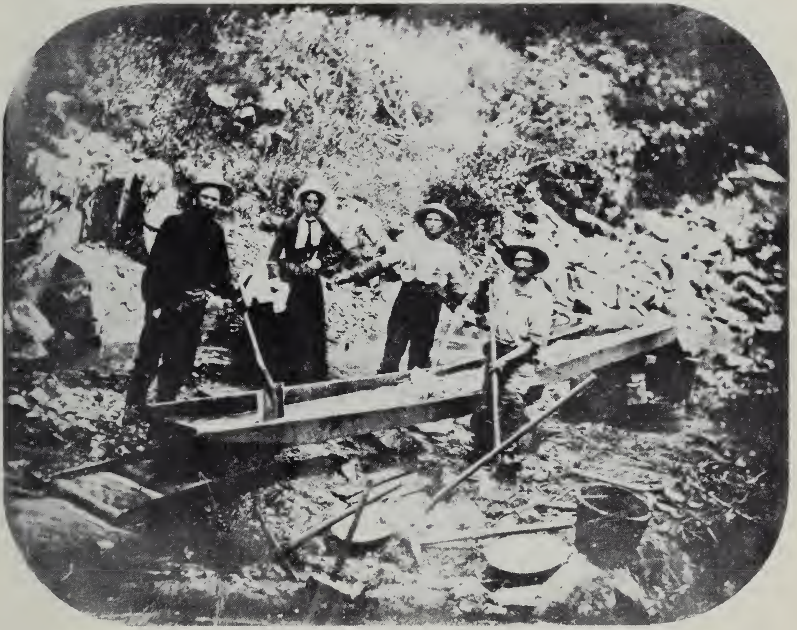


FIGURE 60. IN AUBURN RAVINE, 1852. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

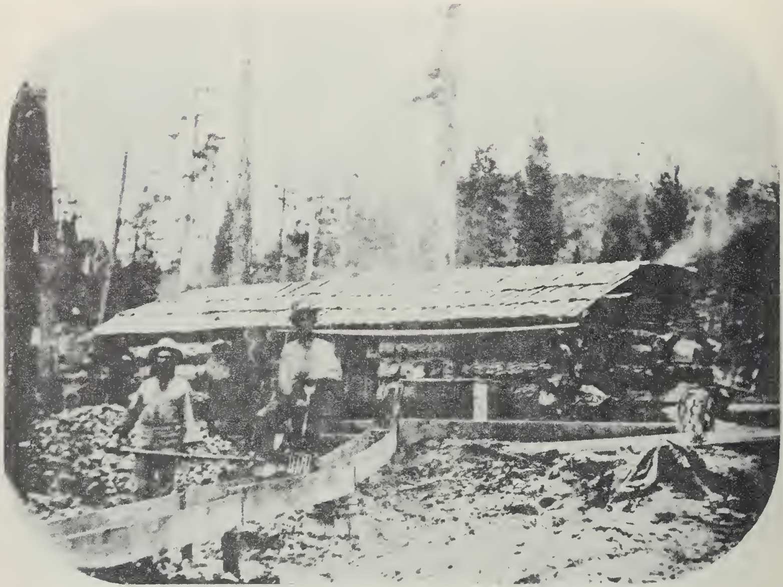


FIGURE 61. NEAR SUGAR LOAF HILL, 1852. Daguerreotype from the collection of the California State Division of Mines, now on permanent loan in the California State Library, Sacramento; photo by courtesy of California State Library, California Section.

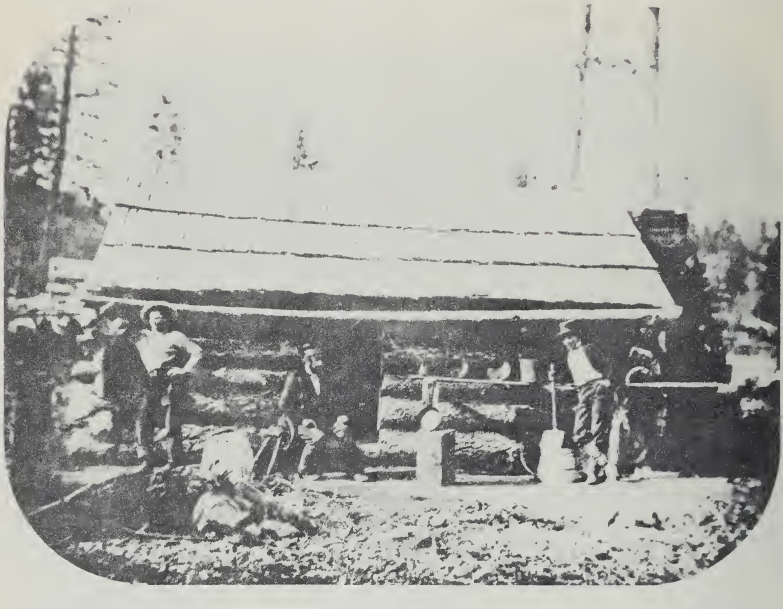


FIGURE 62. MINER'S LOG CABIN, 1852. Daguerreotype, depository unknown. Photo by courtesy of California State Library, California Section, Sacramento.

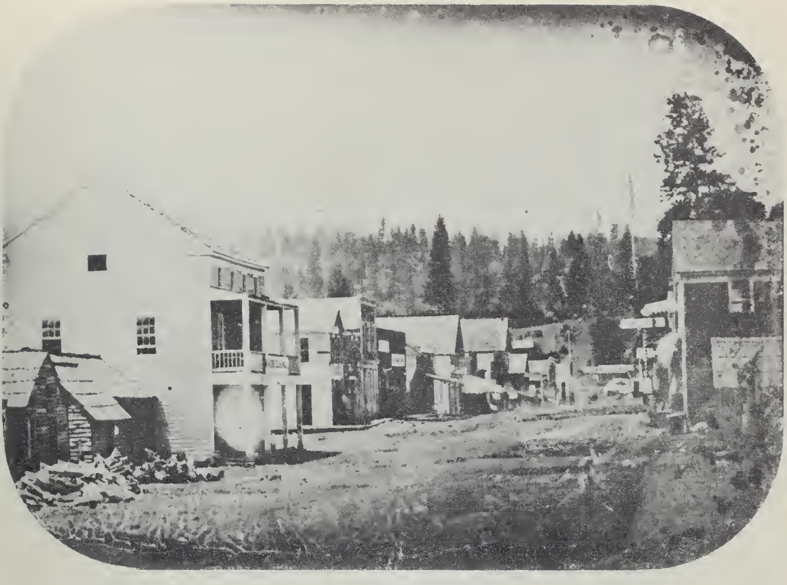


FIGURE 63. MURPHY'S, CALAVERAS COUNTY, ABOUT 1852. Daguerreotype from the collection of Frederick S. Baker, Berkeley; photo by courtesy of Dr. Baker. The daguerreotypes represented in figures 63, 65, and 66 were made by Isaac W. Baker and his partner Mr. Batchelder, probably in 1852.

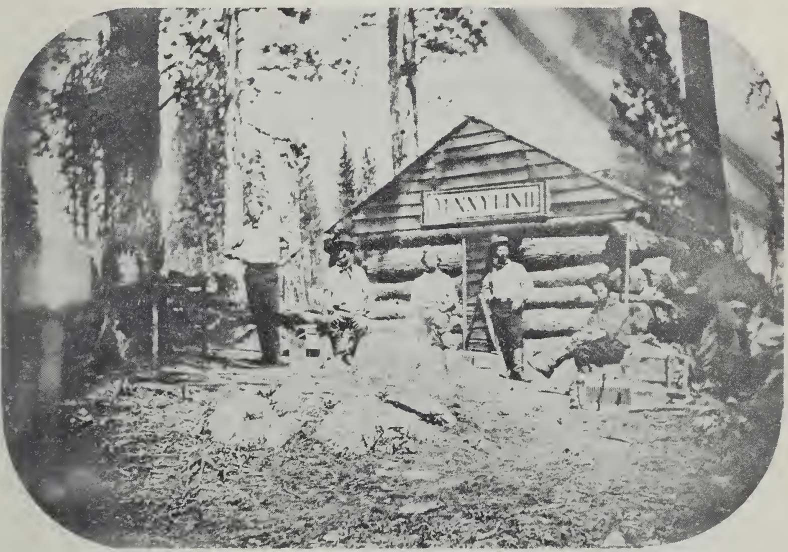


FIGURE 64. MINERS' CAMP NEAR GRASS VALLEY IN THE FIFTIES. Daguerreotype from the collection of Sutter's Fort Historical Museum, Sacramento; photo by courtesy of Sutter's Fort Historical Museum. A notation accompanying the daguerreotype states that the camp was in a ravine between Nevada City and Grass Valley. During high water in Deer Creek the Jenny Lind Theatre was washed away; and the sign, which floated down, was found and nailed over the door of the cabin. The three pairs of brothers shown in the picture—Forest G. and Phineas M. Jefferds, Josh and Henry Moore, and Andrew and Perry Knettle—were mining partners. Forrest G. Jefferds, standing under the sign in the center of the picture, arrived in California October 5, 1851. Daguerreotype donated by Hazel Watrous, his granddaughter.

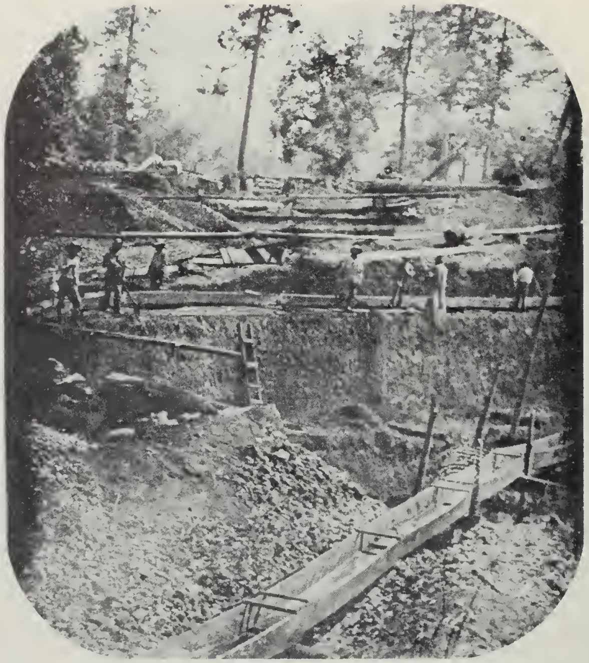


FIGURE 65. NEAR MURPHY'S, CALAVERAS COUNTY, 1852. Daguerreotype from the collection of Frederick S. Baker, Berkeley; photo by courtesy of Dr. Baker.

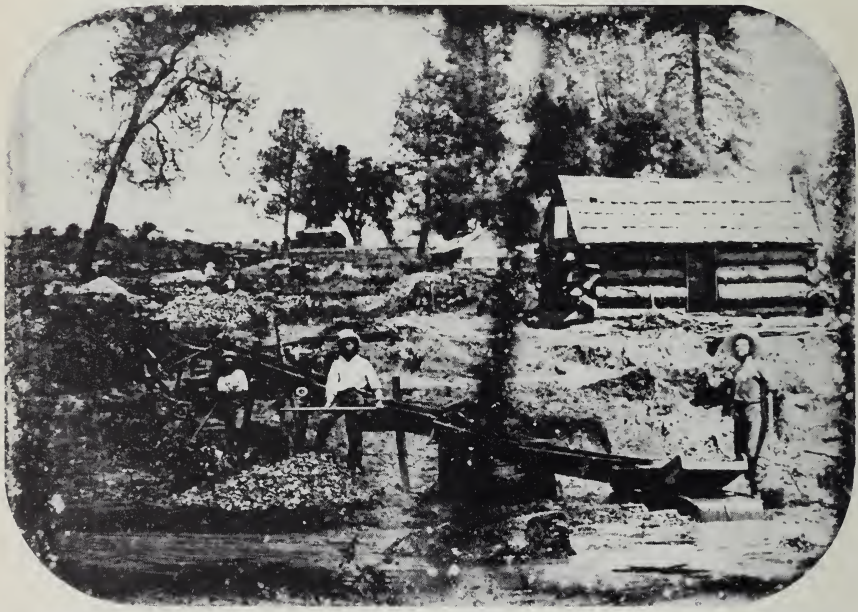


FIGURE 66. NEAR MURPHY'S, CALAVERAS COUNTY, 1852. Daguerreotype from the collection of Frederick S. Baker, Berkeley; photo by courtesy of Dr. Baker.

THIS BOOK IS DUE ON THE LAST DATE
STAMPED BELOW

BOOKS REQUESTED BY ANOTHER BORROWER
ARE SUBJECT TO IMMEDIATE RECALL

JAN 0 6 1988

RECEIVED
SEP 22 [illegible]
PHYS SCI LIBRARY

NOV 6 1990

RECEIVED
DEC [illegible] 1990

JUN 3 0 2002

JUN 3 0 2003

RECEIVED
APR 2 [illegible] 2003

RECEIVED
APR 2 6 2003
PSL

LIBRARY, UNIVERSITY OF CALIFORNIA, DAVIS

Book Slip–Series 8

Call Number:

111574
California journal of
mines and geology.

QE89
A1
C3

Calif.

GEOLOGY

QE89
A1
C3
V.45

111574

3 1175 00459 3979